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ABSTRACT

Most of the papers and summaries of papers presented at the twelfth annual conference of the Australian Science Education Research Association are presented. Topics addressed focus on various aspects of science curriculum and instruction, teacher education, student and teacher characteristics, and learning. Papers presented include, among others, science education and philosophy of science; science teacher participation in reviews of syllabi; effects of practicing teaching on students' attitudes to teaching science; prospective versus retrospective synthesis of science teaching in the United States; childrens' drawings of natural phenomena; phases of a research project (description, analysis, action); student/teacher views of unsolved problems in biology; use of problem-solving in meaningful learning in biology; case study analysis of differences in learning processes/outcomes in biology; use of cognitive mapping in teaching/learning strategies; learning a procedural task; theory of learning in tertiary science education; nature of learning/cognitive styles; teacher transmission/interpretation and students' attitudes to science; formal school/attitudes of Papua New Guinea students (1972-1980); implementation of a personalized system of instruction in physical science and comparison of attitude and achievement with conventional classes; and student perceptions of influences of practical work in science at high school and matriculation levels in Tasmanian schools. (Author/JN)

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**RESEARCH
IN
SCIENCE EDUCATION**

VOLUME 11

Proceedings of the Twelfth Annual Conference of the Australian Science Education Research Association, University of Tasmania, Hobart.

May, 1981

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PREFACE

This publication contains most of the papers and summaries of papers presented at the twelfth annual conference of the Australian Science Education Research Association. The conference was held at The University of Tasmania, Hobart, on 14-16 May, 1981.

As is usual, no theme was nominated for the conference and a wide distribution of topics, approaches and levels was represented. The papers as they are arranged proceed from the field of endeavour which concerns itself with the education and practices of science teachers. A beginning is made when a viewpoint is provided to support a hypothesis suggesting that a study of philosophy of science by teachers and scientists may result in improved articulation of science. There follows a group of papers that place emphasis upon teaching practices as these relate to curriculum and particular skills. These papers cover the teaching of science at all levels including that of primary school children. To some extent the perspective then changes to one that is on considerations of curriculum including student practical work, and the relationship with teaching, learning and attitudes can be observed. The interesting development in cognitive studies of learning as related to science education, teaching strategies and curriculum is well represented. Finally Volume 11 concludes with further studies on attitudes and expectations as these apply firstly to an aspect of teaching style and then to activities, topic and subject areas.

Laurie Rattray-Wood
Editor

Research in Science Education, 1981, 11, 1-7

SCIENCE EDUCATION AND PHILOSOPHY OF SCIENCE

Don Margetson

The suggestion has been made that the teaching of science may be improved if science teachers studied philosophy of science in addition to more traditional concerns (Scheffler 1973, and Gardner 1975, for example). Here I shall consider only Scheffler's view by outlining a central part of his argument on this matter, discussing difficulties arising from his position, and attempting to outline a more satisfactory view of the relation between science education and philosophy of science.

The following excerpt indicates the kind of criticism Scheffler had of an existing state of affairs :

... prevalent conceptions of teacher training are curiously restricted. For these conceptions typically emphasise three features : subject-matter competence, practice teaching, and the psychology and methodology of teaching. Since subject-matter competence is, moreover, interpreted as relating exclusively to the first-order proficiency of the practitioner, no attention is given to the need for second-order, or philosophical, perspective on the subject-matter in question. (Scheffler, p. 214)

The distinction between first-order and second-order activities is understood in terms of the object of thought in those activities. In the case of the natural sciences the object of thought is the natural world, or at least aspects of it. Scientists are engaged in first-order activities since their thought is about things in the world. A second-order activity takes as its object the thoughts of first-order activities. In the case of science, to engage in this second-order reflection is to engage in philosophy of science. Scheffler then introduces the notions of embodiment and articulation in connection with first-order and second-order activities. The form of thought called science is embodied in the first-order practices of scientists. That is, scientists make use of various theories in their thinking about natural phenomena, they adopt particular methods in their investigations and they conform to certain standards in their work, all of which is an embodiment of scientific practice. If scientists understand these theories, are adept in the use of appropriate methods, and conform to certain standards then they will satisfactorily embody scientific practice and can fulfil their functions as scientists. In order to achieve this they will not, according to Scheffler, need to engage in second-order reflection on their first-order activities.

In contrast to this, the second-order reflection which constitutes philosophy in general and, in our example here philosophy of science in particular, is an articulation of the first-order form of thought. This articulation has as its purpose the identification and critical appraisal of the first-order forms of thought. Scheffler wishes to argue that the teacher is unavoidably

confronted by such second-order matters since part of teaching science is the communication of the aims, methods, standards, and scope of science. If the teacher is to teach these matters satisfactorily it seems important that he or she should have thought them through clearly. Moreover, the teacher is inevitably faced with the question of the selection of matter to be taught: not everything can be taught in any formal course of study. If he is to select teaching matter which is most likely to result in his students' successful learning of science then this will require the teacher to reflect carefully on the nature of science and what he is trying to help his students learn about it. In thinking about these matters the teacher is not thinking directly about the natural phenomena in the world that the scientist studies; rather, he is thinking about how best to introduce students to the form of thought in terms of which these phenomena are studied. The teacher is therefore, in this aspect of his work, engaging in second-order articulation of science rather than in first-order science. The position that Scheffler leaves us in, then is essentially this. The scientist need learn science only in such a way as to embody sound scientific practice in his work. But the teacher of science needs in addition to articulate these practices so as to be able to teach science effectively. In Scheffler's own words :

To acquire the traditional mental habits of the scientist ... requires only that one learn how to deal scientifically with some range of problems, and to treat critically of the materials bearing upon them ... (The philosopher's) task, in short, is to articulate and analyse the forms themselves, and to try to understand their point. (p. 215)

The position seems problematic. It seems to leave scientists in a limited one-dimensional frame of mind, while their teachers are in a more advantageous position since they can not only embody scientific practice but also articulate it. However, the distinction between embodiment and articulation does not seem necessarily to be connected with the difference between working as a scientist in contrast to working as a teacher of science. Rather, as I shall try to argue, the distinction between embodiment and articulation seems to be connected with a difference between what I shall call an educated practitioner in contrast to a merely trained practitioner, and the distinction between them applies to all practitioners irrespective of whether they work as scientists or as teachers of science.

A central matter in Scheffler's position which seems problematic concerns the question of how first-order practitioners know whether or not what they are doing is right or appropriate or worthwhile. An apparently attractive answer to this question is that they know they are proceeding correctly if what they do works. But this answer is plausible only in so far as the aims of the work, and the standards in terms of which it is to be judged, are clearly understood. On what grounds could the scientist make judgements about these aims and standards? Scheffler's distinction between embodiment and articulation seems to leave us with an uncomfortable answer if we have to answer the question in terms of the distinction. On his account scientists need only embody scientific practice and not articulate it, and it is possible - indeed normal - for scientists to embody this practice without articulating it. The ground available on which the scientist can make such judgements appears to be only whatever is embodied in existing scientific practice. Given the embodiment is by definition non-articulative it appears that the scientist is at the mercy of whatever views are embodied in the current orthodoxy of scientific practice. In other words, the scientist is put in a position to make critical use of various theories, methods, and standards in first-order practice, but he is not put in a position to reflect critically on these outside of the normal scientific use of them.

This seems a strange limitation of the position in which one would expect to find the scientist, for science has an ethos of open-mindedness, rigorous criticism in the interests of finding truth, and a willingness to follow the route indicated by such discovery. On Scheffler's view the scientist does exercise a critical function but this is only at a first-order level. On such a view the critical function is generally limited to evaluating theories in relation to empirical evidence, and this is of course a very important function.

But why should it be thought that this is the only legitimate, or even the only useful, kind of criticism beneficial to science? Perhaps it is the result of an over-reaction to earlier excessively speculative kinds of thinking, particularly of the arid scholastic variety which solemnly debated such matters as how many angels could dance on the head of a pin. This over-reaction may be considered to have reached its peak in the form of logical positivism with its rigid insistence on the verification principle which asserted that the meaning of a statement consists in its method of verification and the corollary that statements which could not be empirically verified were meaningless. But this appears to be absurd since the verification principle itself has meaning and indeed must have meaning before it could be put to any empirical test; if this were not so we could not understand what test to apply to it. Possibly it is the after-effect of logical positivism which causes the belief that only first-order criticism is legitimate or useful. However that may be, there are in any case grounds for thinking that second-order criticism is both legitimate and useful in science.

An example illustrating this is Popper's replacement of the notion of verification by that of falsification in regard to general theories. This may be outlined in the following way. To verify something means to show that it is true. Empirical verification requires observation of some kind. But in the case of general theories (and general laws) about natural phenomena not all instances covered by the theory can be observed. This being so we cannot be sure that any future observations of instances relevant to the theory will in fact support it, and therefore the theory cannot be said to be verified. But if an observed instance runs counter to the theory in question then the theory cannot be true. Thus a general theory concerning natural phenomena can be falsified but not verified. This kind of philosophical criticism of the notion of verification has clear implications for the conduct of scientific practice. It suggests and provides a justification for the methodological principle that experiments and tests of theories should be as varied as possible in order to try to falsify the theory. If the theory withstands these attempts at falsification then we may place a fair amount of confidence in the theory, even though we cannot say that it has been verified. The philosophical criticism also clarifies the status of theories since in the light of the criticism they can no longer be regarded as certain or as secure as they were thought to be when the idea of verification was received doctrine.

It seems then, that articulation - that is, second-order, philosophical matters - may have profound influences on what is regarded as sensible scientific practice, and on the nature of science. This is as relevant to the practising scientist as to the teacher of science. In opposition to this it would seem that if scientists can fulfil their functions adequately by only embodying scientific practice then it would seem plausible to believe that teachers can do the same; in any event, they seem at least to have been getting by in this way up till now. In other words, it seems that if articulation is of benefit then it is of benefit to both scientists and

teachers of science; and if practitioners can get by without it then both scientists and teachers of science can get by without it.

However, the idea that these practitioners can get by without articulating their discipline does present difficulties for the idea that science is a rational activity. Suppose scientists or teachers of science wished to improve their practices. A number of ways would be open for the achievement of this improvement. The practitioners could, for example, study more science, or hope that practice would lead to gradual improvement, or depend on intuition to reveal ways to improvement, or leave it to chance, and so on. Although some of these constitute an extension of the embodiment of practice, none of them is an articulation of scientific practice. Articulation is a rational process; if this is omitted from the number of ways for improvement open to the practitioner then how could science defend its claim to be a rational activity? Could it not be reasonably expected that articulation could result in a practitioner coming to better understanding his practice, to see it in a new light which would cause him to change his practices, and to work out the justification of his activities? If these possibilities exist then could ignoring them not be regarded as choosing to rely on chance, luck, or intuition rather than on rational grounds? This is not of course to deny that chance, luck, and intuition can play a part in anyone's work, including that of the scientist; it is only to suggest that if reliance is placed on these matters when there is a better alternative available - namely, rational deliberation - then the claim to rationality must be questionable. There does not appear to be any good reason why scientists should be burdened with this sort of irrationalism necessarily. Indeed such irrationalism goes against the ethos of science mentioned earlier, particularly in so far as it contradicts the belief that historically the emergence of modern science is to be explained in terms of a rational and empirically based struggle to free thought from the superstitious and dogmatic chains of mediaeval scholasticism.

The matters considered so far appear to suggest that while Scheffler's distinction between first-order, or embodied, activity and second-order, or articulated, activity is sound, the application of this distinction is misplaced. First-order activity, while perfectly appropriate and useful so far as it goes, is nonetheless limited by being first-order. The nature of this limitation is specifically associated with an absence of articulated reflection on the aims, methods, and standards of the activity in question. The consequence of this is that the first-order practitioner will be able to make use of his knowledge in relation to the natural phenomena he studies, but will not have been systematically prepared to stand back from his practice, as it were, to consider the aims, methods, and standards of these practices; that is, he will not be well prepared to articulate the practices. This is precisely the kind of limitation that could be expected in someone who had only trained to do something, in contrast to someone who was able to do something in a much more understanding and informed way. Training, in its crudest and most basic sense, leads typically to persons being able to do the things the training is about, but without having much or any understanding of the articulation of the activity in question.

This becomes crucially important if matters of embodiment and articulation are recognised as inevitably involving questions of value. In the case of science certain aims, methods, and standards are judged to be of value. Respect for facts and for logical argument, carefully controlled experimentation, and replicability of experiments by other workers are, for example, matters which are judged to be of central value in science. They are values which can be supported by reason but they are values

nevertheless. In the case of persons trained in the crude sense at present under consideration, it is typical that decisions about the values assumed in the activity in which the person has been trained are taken by persons other than the trained person. The autonomy of the trained person is therefore seriously compromised, since his attention is directed toward the matter of how to do something without any consideration by him of the specific second-order questions mentioned above regarding the values assumed in the activity. In this sense the trained person is tantamount to being merely an instrument of others. For others take the decisions about whether anything shall be done, what shall be done, what the justification for it is, and so on, while the trained person is left, in this matter, only with the limited ability provided by his training.

The kind of training which leads to this kind of situation is only training of the crudest and most basic sort. It represents the worst extreme of training in that from a second-order point of view it reflects largely thoughtless activity. But this extreme concept of training cannot very easily accommodate a kind of training which is specifically not thoughtless, that is, intellectual training. Nevertheless, intellectual training can still be seen to be a form of training and to carry with it the potential dangers which accompany any training. Intellectual training, just as other kinds of training, can suffer from a preoccupation with questions of simply how to do something at the expense of questions concerning the values assumed in doing that thing. This is not to say that all intellectual training is undesirable. This could not be so since it seems that some intellectual training is a necessary step in any process of relatively developed learning. Nevertheless, some kinds of intellectual training can be undesirable, namely those that lead to indoctrination. In some respects, such as in knowing simply how to do something, the indoctrinated person resembles the merely trained person. For example, indoctrination, being involved with doctrines or systems of belief, results in a person knowing how to repeat or regurgitate the relevant doctrines, but typically it appears that the indoctrinated person merely expresses the doctrines without any real understanding. In the case of non-intellectual training a person may have some merely physical ability which allows others to say that he knows how to do something although he does not really understand what he is doing. The kinds of thing done are of course different in that one is predominantly mental in being concerned with doctrines, while the other is predominantly physical in being concerned with a developed physical ability but both concentrate on how to do something with little or no concern for comprehending the thing in any depth. Both mere training and indoctrination are embodiments of a particular kind rather than articulations; in this they are both first-order matters.

✓ In contrast to this a situation may be envisaged in which a person is competent not only in first-order activities but also in second-order reflection on these activities. In this situation a practitioner would not only be able to make use of specialised knowledge in a particular science but would also be able to reflect critically on the nature and status of this knowledge and to arrive at informed and considered judgements on these matters. Such a practitioner might be described as educated rather than merely trained. The word "merely" is an important qualifier here, since it is not the case that training and education are necessarily mutually exclusive. Training to some extent would be part of anyone's education, but education does not stop at training; it includes training as a necessary part, but nevertheless only as a part of what it is to become educated. With this kind of distinction in mind it is possible to begin to talk of the educated

scientist in contrast to the merely trained scientist, and of the educated science teacher in contrast to the merely trained science teacher. The educated scientist and the educated science teacher would both embody and articulate science, while the merely trained scientist and the merely trained science teacher would only embody science.

The matter does not, however, seem to be quite as straightforward as this statement might suggest. This may become apparent by reflecting on the kind of articulation so far considered, which has been concerned with the aims, methods, and standards of science and has therefore been identified with philosophy of science. This kind of articulation has been put forward as a ground on which to distinguish the educated practitioner from the merely trained practitioner. But is this kind of articulation sufficient by itself to justify the appellation "educated"? The question of aims may provide a convenient way into the problem. Aims which may be identified uncontroversially as scientific in nature are those which satisfy accepted beliefs about the nature of phenomena to be investigated (for example, that quarks but not god are legitimate phenomena for scientific investigation), the appropriate methods to be followed, and the standards to be met in such an investigation. So far as they go these might be satisfactory kinds of criteria in terms of which to identify scientific aims.

But just how sharply can scientific aims be separated from other matters? If often seems to be assumed that because something can be identified as a scientific aim, or more generally a scientific matter, that it can be considered in isolation from other matters - as though, as it were, it could be cut off cleanly from other matters. Now in an obvious sense it is possible to do this. It is possible to conduct a scientific investigation into something, and then simply close the matter there without considering anything further. This is possible in theory, and even in practice. But it is on the question of practice that the problems arise. For the practice of conducting the investigation does not stand in isolation, and nor could it, except under one highly improbable condition. The condition is that the investigator kept the results of the investigation completely to himself, and, moreover, never allowed the results of his investigation to influence in any way any of his subsequent actions. If the results of his investigation influenced any action, whether his own or that of others, then his investigation would have had a practical effect and would therefore not have been isolated from other matters.

Thus while it is true that a scientific investigation may be regarded in some abstract way as complete in itself, it is also true that the investigation is connected with other matters. This unavoidable connection with other matters - except under quite bizarre and unrealistic conditions - seems to have a bearing on the question of the educated practitioner. Consider the case of a scientist who: (1) adopted the view that as a scientist he was responsible only for producing the results of his investigation and that it was none of his business what anyone else did with those results; and (2) was a model practitioner in so far as he both embodied and articulated scientific practice of the kind so far considered. Now, a situation could arise in which some authority wished to suppress the results of the scientist's work; for example where the authority had a vested financial interest in a food product which the scientist's work had shown clearly to be carcinogenic. In accordance with (1) above the scientist could accept this suppression. This seems to be clearly immoral; yet, in the light of considerations argued earlier, because he not only embodied but also articulated scientific practice it was suggested that we could begin to talk about him as an educated practitioner. However,

unless one wishes to devalue the notion of education, it seems contradictory to talk of a person as being both educated and immoral. Consequently it seems that a more complex account has to be given of what it is to be an educated practitioner. The distinction between embodiment and articulation seems substantial, and so does the distinction between an educated practitioner and a merely trained practitioner, but the two distinctions do not appear to bear a simple relation to one another; that is, embodiment is not simply related to one another; that is, embodiment is not simply related to training and articulation is not simply related to education. Rather, it appears that articulation is a necessary condition of someone being regarded as educated but it is not a sufficient condition since considerations which are not specific to a particular discipline or subject form an essential part of what it is to be educated.

The conclusion which appears to follow from these considerations may be expressed in three parts. First, articulation in so far as it concerns philosophy of science is significantly relevant not only to the teacher of science but also to the practising scientist. Second, the notion of articulation in contrast to the notion of embodiment raises the possibility of a distinction between the educated practitioner on the one hand and, on the other hand, the merely trained practitioner and the indoctrinated practitioner. Third, in the case of science, this distinction can be sustained only by recognising that the connection between articulation and education requires that articulation be understood as involving both philosophy of science and wider matters.

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SCIENCE TEACHER PARTICIPATION IN REVIEWS OF SYLLABI
- MORE THAN AN ORGANIZATIONAL DILEMMA

Rod Fawns

More than a decade has passed in Victoria since the publication of the last Junior Science Course prescriptions and examinations syllabi leading to the old year 10 Science Examination. Responsibility for the science programme passed effectively to science departments in schools led often by a rather powerless figurehead, the science coordinator. Fawns (1978) briefly reviewed the history of centralized attempts to develop junior secondary science from 1943 when general science replaced separate sciences at this level.

In 1978 a series of inservice seminars, known as the "Developing a Four Year Science Syllabus" (DAFYSS) Workshops, was launched and has now been attended by teachers in over 350 secondary schools. These were funded by the Schools Commission and administered through the Victorian Inservice Education Committee. This article does not set out to describe the workshop programme (available from Science Teachers Association of Victoria). Rather, it records one organizer's attempt to calculate the impact of the workshop, not in isolation but in the context of curriculum innovation to which participants returned.

The primary focus of the two day workshops was on the description, analysis and criticism of the syllabi and supporting documents tabled by each participant working in a group of about eight teachers.

A questionnaire was mailed in October 1979 to all participants in workshops held in 1978 and early 1979. The following broad questions were asked:-

- (1) In retrospect, to what extent were certain objectives of the workshop attained?
- (2) Should the workshop have been more prescriptive in style?
- (3) What environmental factors influence science teacher participation in curriculum development?
- (4) What view of professional responsibility did the workshop present?
- (5) What is the status of syllabus review and subject coordination amongst school priorities?

The Sample Questionnaires were sent to all 131 workshop participants in 125 schools. This sample of 125 schools represents about 18% of Victorian high, technical, independent and Catholic secondary schools.

In all, 69% of those schools eligible and 12% of all Victorian secondary schools responded. This is a more than adequate sample of the population of participants if returns represent a random sample. Early and late returns were compared and no significant differences on any items were found. There seems to be good reason to believe that this sample may be representative of early participants in the workshops. There is, however, much less certainty about the representativeness of the sample in relation to the environment of syllabus review in all Victorian secondary schools. Participants are taken to be curriculum workers interested in and generally responsible for the junior science programme in their school. Two-thirds of respondents were current science coordinators and others had been coordinators. The science syllabus

is taken to be the publicly accountable documentation, including aims : statements of hopes for the students and assessment aims, distribution of responsibilities, coherence within and between levels, and major conceptual emphases. The science curriculum refers more broadly to those learning experiences which the science staff plans for students.

1. "To what extent do you consider in retrospect that the objectives of the workshop have been attained?"

The average ratings in Table 1 give an indication of the confidence with which these improvements were asserted. Participants were most confident of their increased ability to identify the processes involved in developing a syllabus and to produce a practical plan of action, but were less confident about their abilities to carry others with them. In particular, they were less confident

TABLE 1 - Objectives and their Attainment

Objective (N = 86)	% agreement	av. rating on scale 0-3
(a) I am more able to identify the processes involved in developing a science syllabus within my school.	91	2.21
(b) I am more able to work effectively as a member of a curriculum development team within my science department and school at large.	86	2.12
(c) I am more able to describe and discuss various factors influencing the determination of aims and objectives for various age levels of my science and school curriculum.	75	1.95
(d) I am more able to apply strategies related to		
1) collecting information about curriculum	82	1.98
2) making effective decisions about curriculum	78	2.01
3) improving communications both vertically and horizontally within the school administrative structure in relation to curriculum development.	59	1.85
(e) I am more able to produce a practical plan of action for improving the process of curriculum review and development in my school science department and in the school at large.	77	2.20
(f) Did you feel you have, as a result of the DAFYSS workshop		
1) a better understanding of the principles of curriculum analysis	89	2.12
2) a greater self-confidence	70	2.07
3) a deeper commitment to education	46	1.70
4) a greater sense of accomplishment in the efforts and directions already taken?	71	2.11

about their ability to influence administrative practice, settle problems of establishing aims and objectives and collect information about the curriculum. Factor analysis of the items of Table 1 suggests the respondents recognized three underlying principles. The dominant factor grouped items such as a, b, c, d3 and f1 which express feelings of greater intellectual authority. A second factor highly associated with item f4 recognized affective support derived from the workshops. The third factor associated with items 4, f3 and d1 indicated participants desired encouragement to take a leadership role. Discriminant analysis distinguished between the sense of accomplishment experienced by participants from state schools compared with those from independent schools. The former drew less satisfaction in their accomplishments than the latter.

2. Environmental factors influencing teacher participation.

"To what extent do you agree or disagree that the following factors have significantly limited the participation of teachers in junior science syllabus review and development in the science department in your school?"

The results are summarized in Table 2.

Factor analysis of the items of Table 2 suggests that respondents recognized three important factors which limit participation. The strongest association was between items k, j, b, f and e, all of which relate to the problem of understanding the complex factors impinging on curriculum development in a school. The second factor associated with items d and h refer to staffroom morale. State school membership loaded this factor. The third factor grouped items c and a and referred to the problems of establishing school priorities.

External influences in the form of "ambiguous official statements about the teacher's role in curriculum development" or "inadequate theoretical models offered in service programmes" are least significant. The fact that these factors are perceived as less important may indicate the isolation of curriculum policy development from direct outside influence. (Ogilvie & Bartlett, 1973, Cohen & Harrison, 1978) It may just as well refer to the rarity of such statements in this area. There was, moreover, considerable evidence here that participants were seeking to understand rather than resist external and internal influences on science curriculum policy.

3. What view of professionalism did the DAFYSS organizers present?

Respondents were asked to indicate by their reaction to each pair of statements in a likert scale format

- (a) what science teaching is like, and
- (b) what the DAFYSS organizers-speakers felt science teaching should be like.

These data are presented in Table 3. The paired statements are listed down the left and right vertical axis, respectively. The large gap between perceived expectations and actual commitment amongst science teachers was reflected in the relatively large contrast between the mean ratings.

In relation to specific attributes, the greatest discrepancies were observed to be in discussion of teaching methods (1.6), professional reading (1.3) and interest in curricular work (1.3). Earlier responses suggest that many workshop participants saw themselves occupying a middle ground on many of these variables and that these three items may also indicate problems not formed by the workshops but facing those currently attempting to commit colleagues to curriculum reform.

TABLE 2

Factors which limit the participation of service teachers in syllabus review

	% agreement	av. rating on scale 0-3
(a) Conflicting priorities of teaching; lack of incentive to teachers to engage in planning and evaluation.	81	2.13
(b) Complexity of issues and of managerial problems	67	1.67
(c) Inadequate allocation of resources; rigidity and bureaucracy in control of resources	62	1.79
(d) Lack of interest or conviction in staff, particularly in sustaining change processes over a period of time.	62	1.78
(e) Reconciling what may be conflicting demands on the school.	55	1.66
(f) A sense of low self-esteem and inadequacy in staff, and lack of relevant skills.	53	1.53
(g) A tendency to select prematurely one strategy or style in preference to possible alternatives which singly or in combination may be more effective.	53	1.53
(h) Tension and subtleties of group interactions when the balance of power in the department is threatened.	49	1.50
(i) Ambiguity of various official statements about the teacher's role in curriculum development. *	37	1.41
(j) Rapid staff turnover.	37	1.36
(k) Inadequacy of theoretical models, inservice teaching and jargon.	35	1.32

* These data were collected before the Minister's Green Paper on Strategies and Structures for Education.

TABLE 3
Curriculum Workers' Perceptions of the Attitudes of Science Teachers
and Inservice Organizers to "Extended Professionalism"

	mean rating of attitudes of science teachers on on a scale 1-5	mean rating of attitudes of inservice organizers' on a scale 1-5	
a ₁ Science teaching skills are derived from the interplay of experience & theory rather than experience only.	3.1	3.7	a ₂ The DAFYSS organizers felt science teaching skills should be derived from the interplay of experience & theory rather than experience only.
b ₁ Classroom events are perceived in relation to school policy & goals rather than in isolation	3.3	4.1	b ₂ The DAFYSS organizers felt classroom events should be perceived in relation to school policy & goals rather than in isolation.
c ₁ Science teachers tend to seek discussion with colleagues rather than be introverted about methods.	2.6	4.2	c ₂ The DAFYSS organizers felt science teachers should seek discussion with colleagues rather than be introverted about methods.
d ₁ Science teachers take pride in participation in school wide work rather than in work centering on instructional outcomes & relationships with students.	2.7	3.3	d ₂ The DAFYSS organizers felt that science teachers should take pride in participation in school wide work rather than in work centering on instructional outcomes & relationships with students.
e ₁ Science teachers read professional literature regularly.	2.7	4.0	e ₂ The DAFYSS organizers felt science teachers should read professional literature regularly.
f ₁ Science teachers' involvement in inservice work includes courses of theoretical nature rather than being confined to practical courses.	3.1	3.5	f ₂ The DAFYSS organizers felt science teachers should be involved in inservice work including courses of theoretical nature rather than being confined to practical courses.

TABLE 3 (cont.)
Curriculum Workers' Perceptions of the Attitudes of Science Teachers
and Inservice Organizers to 'Extended Professionalism'

g ₁ Science teachers seek the opportunity to become more active in curriculum work	3.2	4.5	g ₂ The DAFYSS organizers felt science teachers should seek the opportunity to become more active in curriculum work.
h ₁ Science teachers do participate in determining the basic outline of a curriculum & detailed content rather than determining texts and instructional materials.	2.5	3.2	h ₂ The DAFYSS organizers felt science teachers should participate in determining the basic outline of a curriculum & detailed content rather than determining texts & instructional materials.

Factor analysis and varimax rotation of the 16 items suggests four underlying patterns. Together these four factors accounted for 72% of the total variance. The item structures for the first two factors (each accounting for about 20% of the variance) are shown in Table 4.

TABLE 4

FACTOR 1		FACTOR 2	
"extended professionalism of the organizers"		"extended professionalism of teacher"	
a ₁	+ .49	c ₁	+ .37
a ₂	+ .46	e ₁	+ .60
c ₂	- .73	g ₁	- .77
d ₂	+ .34		
g ₂	+ .35		
h ₂	+ .31		

(only items with factor loadings greater than .30 are shown)

Factor 1 grouped the items which relate to the organizers' perception of science teaching. The DAFYSS speakers were clearly seen to be presenting a distinct but remote ideal for science teaching associated with a collegiate professionalism (Hoyle, 1974 and Lortie, 1975). Discussion and collaboration amongst science staff in schools was seen to be central to the extended professionalism perceived in the organizers. In item a₁ and a₂ "theory" can be taken to refer to scientific rather than educational principles.

The second factor shows curriculum workers' perceptions of science teachers. They found their colleagues do not seek involvement in curriculum work (g_1), do not read professional literature (e_1), nor seek to discuss methods (c_1). Once again, curriculum workers perceived this independently of school policy. State school membership is associated with this pattern of response. Just what these teachers define as professional literature is important but unresearched here. However, it is not restricted to official literature.

The third factor is strongly associated with items e_2 and g_2 , the desirability of reading professional literature (.93), and of being active in curriculum work (.33). It appears that the organizers left no integrated image of the science teachers reading science education literature and applying the principles to everyday analysis. It appears that they may have left the impression that there is a theoretical dimension to curriculum work which is illuminated by a literature to which they have been barely introduced. The factor analysis suggests that another sort of reading is associated with the day to day initiatives of the isolated curriculum worker recognized in factor 2.

Factor 4 is uniquely associated with item h_1 , "teachers participate in determining tests and instructional materials rather than the basic outline of a curriculum and detailed content". It seems likely that the determination of the basic outline and detailed content has generally been left to individuals of the type to whom the workshops appealed most.

To the curriculum workers, the DAFYSS organizers were seen to represent an extended mode of professionalism which was at variance, if not at odds, with a more restricted responsibility espoused by most science teachers who find satisfaction primarily in the autonomy of their classrooms. Questions of boundary, continuity, coherence and personal and cultural value in basic science education have been addressed rarely in a syllabus but probably frequently enough by individual teachers in their classes. There is evidence that these questions are now recognized to be real and significant by many teachers.

In a period in which public scrutiny of schools is intensifying, and attention drawn to these questions, professional satisfaction is increasingly experienced in the collective or collegiate character of science teaching. Put another way, if science teachers wish to limit the ambiguity of their role, they must seek a greater control over their work situation. The achievement of greater control over their work situation implies an increased degree of collaboration with colleagues and others. This was, it seems, a major message of the workshop programme.

GENERAL REVIEW

Young (1979) concluded that, in Canada, "Changing the context for curriculum decision making from the central office to the individual school has the potential for placing teachers in a responsible, active role."

The commitment of the curriculum workers in this study would support that general proposition. These teachers have shown that they feel it is appropriate that decision making about science programmes should occur in a social setting close to the instructional setting and would find any attempt to return to an external prescribed syllabus to be not only inappropriate but impractical, given their experience of the special needs of different school

communities. The challenge has been accepted in many schools (Learmonth, 1979 and Hicks, 1979). However, a number of inhibiting factors which Young identifies with centralized decision making are also recognized by respondents attempting to lead school based curriculum reform. The problems of school based curriculum development anticipated by Skilbeck (1975) have been given empirical substance in this study. This study indicates that in many schools these problems tend to impose a determining role on coordinators whilst the coordinators and the staff feel that fuller participation is conducive to staff development and the improvement of science teaching in the school. This finding is consistent with a group of studies, Cohen & Harrison (1978), Deer (1978), Bartlett & Ogilvie (1978), which have recently examined the role of the head of departments in curriculum development in Australian schools.

Whilst teacher collaboration in curriculum policy making is usually discussed as an organizational dilemma, this perspective masks the fundamental issues of how the syllabus is perceived by curriculum workers in schools. Prescribed syllabi and published materials have always been perceived by their authors as a form of influence over people. Discussions in the workshops on content and purpose in a syllabus were discussions about the character of that influence on teachers and pupils. Basic presuppositions about human nature, the significance of personal experience and valuing as a form of knowing clearly underpin syllabus content and style. Egan (1979) has addressed the effect of prescribed presuppositions. In attempting to redevelop science syllabi these curriculum workshops have excavated presuppositions of the old science syllabi and raised questions about alternative foundations. The curriculum dilemma seen from this perspective is that this analysis requires considerable sharing between staff and the quality of sharing goes well beyond the superficial level which Jackson (1968) found typifies exchange in staffrooms.

School science curriculum review seems to be generally perceived by the curriculum workers as a process of successive approximations to some desired objectives. Along the way, what is desired itself appears to be clarified and changed under the influence usually of decisions made at higher levels. Generally no assumptions are made about a consistent hierarchy of values among staff, only that a rational selection will be made from alternatives available in order to achieve whatever goals (rational or not) the staff has in mind. Participants expressed mounting scepticism that the uncoordinated contest between partisan interests of Physics, Chemistry and Biology is capable of producing any more coherent science syllabi than it has produced in the past.

Whilst about half of all Secondary Schools in Victoria have sent one or more participants to a DAFYSS workshop since 1977, the public investment through the Commonwealth Schools' Commission has totalled less than \$30,000 and more than half of this was paid in salaries to replacement teachers. Averaged over the 14 years since prescriptions ceased, this scale of investment does little to honour the significance of the task being undertaken by curriculum workers in schools.

A policy of inviting 'delegates' from schools rather than teams was a reflection of the desire of the Standing Committee to reach as many schools as quickly as possible. We also felt that in the first instance at least we would get further by supporting individuals who were already moving than by attempting to move all staff in a school. This was no doubt easier as we avoided the intractable problems of inadequate facilities, staff personalities, and student illiteracy and innumeracy in many schools. Given the fact that we had no economic resources of our own, it was probably the only feasible strategy. Whilst that strategy avoided the painful present, it

allowed the organizers to portray a meaningful if challenging future for basic science education in the hands of committed science teachers.

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SOME EFFECTS OF PRACTICE TEACHING ON STUDENTS' ATTITUDES TO TEACHING SCIENCE

Ken Appleton

INTRODUCTION

Practice teaching during pre-service education courses has traditionally been considered a necessary part of the preparation of teachers. While there are undoubted benefits for this "apprenticeship" (Henry, 1978), research has also shown some problem areas, particularly in the development of desirable affects in student teachers (Khan and Weiss, 1973). At least some undesirable changes in affects seem to be a general consequence of practice teaching (Peck and Tucker, 1973).

Some factors which have been identified as influencing attitude change during practice teaching include the supervising teacher's characteristics (Johnson, 1969; Mahon and Lacefield, 1976), student entry affects (Hayes, 1969; Piper, 1976) and subjects studied at high school (Piper, 1976). If student teachers' attitudes to teaching science also show undesirable changes, the influence of practice teaching in determining such attitudes may be significant.

The poor state of science teaching in primary schools has already generated considerable concern (Varley, 1975; Perkes, 1975; Symington, 1974; Henry, 1977). One way of improving practice in schools is to ensure that teachers entering the profession hold positive attitudes towards teaching science.

However it is possible that practice teaching may have detrimental effects on these attitudes. More information is needed about the sorts of changes in affects that occur. It has been reported that student entry characteristics influence attitude change (Piper, 1976). If students with similar entry characteristics exhibit similar attitude changes during practice teaching, then the types of changes in affect could be anticipated for particular groups of students, which could subsequently assist curriculum planning.

This paper examines the question of whether different groups of students exhibit different degrees of attitude change during practice teaching. Variables selected as possibly being related to differences in attitude change were entry affects, sex, and amount of science studied at high school.

The following hypotheses were postulated:

Hypothesis 1: There is no significant overall change in attitude during practice teaching.

Hypothesis 2: For any changes in attitude during practice teaching, there are no significant differences between groups of students with similar entry affects.

Hypothesis 3: For any changes in attitude during practice teaching, there are no significant differences between the sexes.

Hypothesis 4: For any changes in attitude during practice teaching, there are no significant differences between groups of students with similar high school science backgrounds.

PROCEDURE

Investigation of the problem involved surveying student teachers in their second year of a pre-service Diploma (three year) course. A questionnaire surveying attitudes to teaching science was administered to all second-year students (70) several weeks before, and several weeks after, a two-week practice teaching round. The pre-test was administered early to avoid sensitization to attitudes being surveyed. The post-test could not be administered immediately, but the time delay would have allowed attitudes to stabilize. Care was taken to ensure that other factors which could obviously influence affects were avoided during these periods.

Instrument

Using the factors identified from a factor analysis of the use of a previous questionnaire as a basis (Appleton, 1979), two attitude scales were constructed. Scale one, relating to the students' feelings about their own teaching of science, was based almost entirely on the first and major factor. The scale contained eight bi-polar semantic differential items dealing with the students' feelings about teaching science. A value of 0.90 for Cronbach's coefficient α established the internal validity of the scale. The second scale was obtained by a rational process, adding items to one of the other factors. Scale two contained fourteen Likert-type items related to teaching science by inquiry with a "hands on" orientation. This scale was less satisfactory, but a coefficient α value of 0.67 was considered adequate to allow its use as a scale in further analyses.

Grouping of students for analysis:

Since the analysis was being conducted according to entry characteristics, a stratified grouping based on entry characteristics was used. It was necessary to construct dummy variables for each of the entry characteristics being examined in order to identify different groups. While this was an easy task for the variables sex and high school science, a complex procedure was required to obtain groupings according to entry affects. In the previous study a factor analysis was conducted on the pre-test questionnaire data, and five major factors were selected for further study. Factor scores from those factors were used as input for the grouping of students according to entry affects. To aid in interpretation of the groupings, the factors are reproduced in Table 1.

The grouping procedure followed was a hierarchical process developed by Veldman (1967). In group, the cluster analysis used, initially treats every subject as a separate group. In each successive step two groups are selected and combined so that after the last step, only two groups remain; with all subjects having been combined into either of those groups. Selection of groups for combination is made by the minimum increase in total within-groups variance for each step. Steps where dissimilar groups have been joined are characterized by a large increase in the total within-groups variance.

After having established the "natural" groupings from the cluster analysis, differences between the groups were identified using a discriminant analysis. Factor scores were also used as input for this analysis, which not only allowed differences between groups to be determined, but also checked the validity of assigning students to the identified groups.

TABLE 1 - Five major factors

FACTOR	PERCENT VARIANCE	QUESTIONNAIRE ITEMS	ITEM LOADING
1 TEACHING SCIENCE FACTOR	20.9	Try to teach science more often	0.82
		Teaching science is desirable	0.78
		Teaching science is enjoyable	0.76
		Happy about teaching science	0.75
		Teaching science is worthwhile	0.73
		Teaching science is rewarding	0.73
		Feel confident about teaching science	0.71
		Teaching science is important	0.64
2 SOCIAL ASPECTS OF SCIENCE FACTOR	16.5	Science course should emphasise science in contemporary setting, especially social implications of science.	0.76
		An understanding of man's social and interpersonal relationships has a place in the science course.	0.52
3 PUPIL ACTIVITY FACTOR	11.8	Emphasis on activities done by pupil	0.79
		Emphasis on encouraging pupils to decide when question has been answered satisfactorily.	0.69
		Emphasis by teaching on disciplining and controlling pupils.	0.44
		Emphasis on pupils devising and conducting their own experiments.	0.42
4 CHILD INDIVIDUALITY FACTOR	7.4	Pupils should be allowed to work at their own rates.	0.69
		Emphasis on free communications among all members (e.g. open discussions)	0.67
		Major aim of science course should be to develop attitudes - e.g. mindedness	0.51
		Science course should allow for individual differences	0.44
5 SCIENCE CONTENT FACTOR	6.8	Important that science course deal with theories of science	0.56
		Emphasis by teacher on subject matter of the lesson	0.56
		Emphasis on communication from the teacher (e.g. lectures)	0.52
		Emphasis on rules stating how pupils must not behave	0.48

RESULTS

Groupings according to entry affects

In the cluster analysis, there was a considerable increase in the error term in going from three groups to two groups, which suggested that three "naturally occurring" groups existed.

The discriminant analysis revealed that 93% of cases had been correctly allocated to groups according to the dimensions extracted during the analysis. Two dimensions were extracted, each a linear combination of the five factors used as input. From loadings on these dimensions, descriptions highlighting differences between the three groups were deduced. A summary of data and descriptions is in Table 2.

TABLE 2 - Group Descriptions

GROUP	CHARACTERISTICS
1	Quite negative about teaching science, but quite positive about pupil activity; also negative about social and individual development.
2	Quite positive about teaching science, somewhat negative about science content and fairly non-committal about pupil activity.
3	Somewhat negative about teaching science, very positive about science content and very negative about pupil activity.

Discriminant Function Co-efficients

	Function 1	Function 2
Factor 1	-1.09	0.56
Factor 2	-0.20	0.70
Factor 3	-0.39	-0.75
Factor 4	-0.09	0.46
Factor 5	1.07	0.34

Centroids of groups in reduced space

	Function 1	Function 2
Group 1	0.58	-1.41
Group 2	-1.45	0.44
Group 3	1.72	1.41

Analysis

Two analyses were conducted. In the first analysis, t-tests of overall means comparing the pre-test and the post-test scores for each scale were performed. In the second analysis, two three-way analysis of variance with post hoc comparisons were conducted. Differences between pre-test and post-test scores for each scale were calculated for the analysis and used as the dependent variables. Independent variables used were sex, high school science, and groups with similar entry affects as identified above. The post hoc comparisons were performed with the more conservative Scheffé test.

Hypothesis 1: The two scales showed different results on the t-tests. Scale one - teaching science - registered no significant difference between pre-test and post-test. However, Scale Two - inquiry teaching - showed a significant difference, with the post-test having the lower mean. Hypothesis 1 can consequently be rejected for attitudes related to Inquiry Teaching. Table 3 lists summary data for the t-tests. It is also pertinent to note the large change in standard deviation for Scale Two, from pre-test to post-test.

Hypotheses 2 - 4: These hypotheses were tested collectively in the three-way analyses of variance. For Scale One, significant main effects were noted for the variables entry-affect-groups and sex. There were no significant interactions. The post hoc analysis using the Scheffé test set at a probability level of 0.01 revealed a major difference between groups 1 and 2. Inspection of the means for these groups shows that Group 1 experienced a positive change from pre-test to post-test; while Group 2 experienced a negative change.

TABLE 3 - t-Test Data

TEST	NUMBER	MEAN	STANDARD DEVIATION	t
Pre-test Scale 1	54	41.91	6.97	0.05
Post-test Scale 1	54	41.94	5.45	
Pre-test Scale 2	64	56.05	5.10	4.42*
Post-test Scale 2	64	47.19	16.30	
*significant beyond the 0.001 level				

Changes in means for the sex variable reveals that male students experienced a positive change, and that female students experienced a comparatively small negative change.

For Scale Two, the analysis revealed significant main effects for the variables sex and high school science, and significant interactions for entry-affect-groups and high school science. No other interactions were significant. Inspection of the means shows that males experienced a dramatic

positive change from pre-test to post-test, and females a smaller negative change. The Scheffé test set at a probability level of 0.05 revealed that the groups which were significantly different were those with year 10 Science only, and those with a One Year 12 Science subject. The "year 10 Science only" group showed a considerable positive change, and the "one year 12 Science Subject" group showed a small negative change.

From the above findings for Scale One, hypotheses 2 and 3 were rejected for attitudes about teaching science. Similarly, from the findings for Scale Two, hypotheses 3 and 4 were rejected for attitudes about inquiry teaching.

TABLE 4 - Analysis of variance, Scale 1

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIFICANCE
MAIN EFFECTS	486	6	80.918	4.09	p < 0.01
Group	235	2	117.559	5.94	p < 0.01
Sex	143	1	142.786	7.22	p < 0.05
Science	60	3	20.038	1.01	
2-WAY INTERACTIONS	120	9	13.315	0.67	
Group Sex	4	1	4.094	0.21	
Group Science	55	6	9.220	0.47	
Sex Science	64	2	32.299	1.63	
3-WAY INTERACTIONS	59	2	29.740	1.50	
Group Sex Science	59	2	29.740	1.50	
EXPLAINED	665	17	39.107	1.98	p < 0.05
RESIDUAL	692	35	19.786		
TOTAL	1357	52	26.102		

DISCUSSION AND CONCLUSIONS

The lack of any overall change in means in the teaching science scale suggests that practice teaching may have had no effect on these attitudes for the group as a whole. The overall change in means for scores on the inquiry teaching scale supports findings from other researchers (Hayes, 1969; Jacobs, 1968), in that there is an apparent decline in attitudes related to inquiry teaching during practice teaching. The increase in standard deviation for this scale suggests that greater polarization had also occurred. Some students may have remained quite committed to inquiry teaching while others may have revised their opinions considerably. This decline may be related to the fact that few students would have seen any inquiry teaching demonstrated to them, on which they could model their own teaching.

Students with similar entry affects seemed to experience similar types of changes in some attitudes. The group of students most positive about teaching science initially (Group 2) showed a small decline in this attitude; while the group of students initially less enthusiastic about teaching science (Group 1) showed a small positive change. The group of students initially somewhat negative about teaching science (Group 3) could not be differentiated from either of the other groups in degree of change, and showed the smallest change (slightly positive) from pre-test to post-test. These changes could be

TABLE 5 - Analysis of Variance, Scale 2

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIFICANCE
MAIN EFFECTS	22336	7	3190.904	4.43	p < 0.001
Sex	8476	1	8475.924	11.77	p < 0.001
Science	7647	4	1911.751	2.65	p < 0.05
Group	988	2	488.904	0.68	
2-WAY INTERACTIONS	24038	10	2403.792	3.34	p < 0.01
Sex Science	3614	2	1807.186	2.51	
Sex Group	1254	2	627.056	0.87	
Science Group	10871	6	1811.850	2.52	p < 0.05
3-WAY INTERACTIONS	93	1	92.930	0.13	
Sex Science Group	93	1	92.927	0.13	
EXPLAINED	46467	18	2581.510	3.58	p < 0.001
RESIDUAL	31690	44	720.227		
TOTAL	78157	62	1260.600		

explained by changes in self-perception in teaching science by particular groups of students, or alternatively, the possibility of regression to the mean must be considered. Since factor 1, on which Scale One was based, was a major determiner of groups regression could be a real possibility. Hence this result needs to be treated with caution.

A difference in response between males and females occurred in both scales, where male students showed considerable positive changes compared to small negative changes for female students. Consequently it appears that the male students benefitted more than the female students in developing positive attitudes during the practice teaching round. However, there is the consideration that the female students tended to have a higher positive score initially on the inquiry teaching scale. This relationship between sex and initial entry score on Scale Two was checked by a regression analysis which revealed a highly significant relationship. That is, the male students had a lot more room for improvement than the female students, and so could be expected to show a greater change. No such relationship for Scale One existed. These findings raise several questions: in particular, what aspects of practice teaching influence the sex-differentiated changes? Do other attitudes change in similar ways?

A likely possibility is that pupils respond differently to male students than they do to female students. Another possibility is that teachers and administrators treat male students differently from female students. The high percentage of females in pre-service courses makes the study of these questions highly pertinent.

The quite positive change in the inquiry teaching scale shown by students with year 10 Science only, compared to the small negative change in students with one year 12 Science Subject may be related to the comparatively few experiences in inquiry investigations that the "year 10 Science only" group of students may have had themselves.

The students with one year 12 Science Subject had mostly studied biology using the BSCS program, which is supposedly inquiry-orientated. Many of the Year 10 students' science programs would have been textbook orientated. Although the "year 10 Science only" group of students may have been less familiar with inquiry investigations, they seem to have benefitted from their own attempts at teaching inquiry. Perhaps in this way their initial concerns were proved to be imagined rather than real. In comparison, the "one year 12 Science Subject" students may have initially expected too much from the children, and were subsequently disappointed.

The reasons for interaction effects of entry-affect-groups and high school science were not clear, since there was no significant relationship between these variables themselves, as verified using a chi-square test. However, as the science studied at high school may be postulated to influence entry affects in a way not revealed by the chi-square test, it seems reasonably logical that such a relationship existed for these students.

Actual relationships between entry characteristics to a practice teaching round and changes in attitude have been demonstrated for this group of students. If these results can be generalized to other situations beyond the context of this study, some entry characteristics could be used to anticipate changes in affects for particular groups of students. Of special interest and concern is the sex-differentiated changes in both attitudes surveyed. This aspect should be subjected to a more detailed study.

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SCIENCE TEACHING IN THE UNITED STATES: A PROSPECTIVE VERSUS RETROSPECTIVE SYNTHESIS

Robert Yager, Norris Harms and Vincent Lunetta

INTRODUCTION

This paper provides an overview of a comprehensive study that examined discrepancies between desired and actual states of science teaching in the United States. The Synthesis project was a joint effort funded by the National Science Foundation (NSF) has been published by the National Science Teachers Association (1981).

The 1970's were frustrating years for science educators in the United States. The Public appeared to be disenchanted with what it perceived to be science, and there was a decline in support for science education programmes. Furthermore, there was specific criticism of curriculum development and teacher education policies of the National Science Foundation (NSF), and certain curriculum projects, e.g., Man a Course of Study (MACOS), came under attack for a variety of reasons. In 1976 the NSF suspended its support for K-12 curriculum development and teacher education. However, NSF did at that time award three major grants to assess the status of science education from three perspectives. Helgeson, Blosser, and Howe (1977) reviewed all of the research literature relating to the status of science education since 1955. Weiss (1978) studied demographic information concerning curriculum, use of materials, classroom practices, support systems, facilities, and any other information that could be secured by means of questionnaires. Stake and Easley (1978) conducted case studies of eleven schools to study what is actually occurring in classrooms.

After these NSF studies were underway the third assessment of science as a part of the National Assessment of Educational Progress (NAEP) was conducted. It, too, provided information about the results of instruction in science across the United States. Harms, who designed the effective measures included in the third Assessment in Science for the NAEP, initiated a synthesis proposal to NSF in an attempt to identify desired states in specific areas of science education, the actual states in the same areas, and an elaboration of discrepancies between the two. This effort, called Project Synthesis was funded in 1978. The project involved the efforts of 23 science educators representing a variety of perspectives within the science education community.

METHOD

The general research procedure characterizing "Project Synthesis" was a discrepancy model, used more frequently in the social sciences than in the natural sciences. In this design a desired state is outlined followed by descriptions of the actual state. This analysis, points the way to the identification of the discrepancies between the two conditions. With the identification of such discrepancies, recommendations for future action can be made.

The three NSF studies, the NAEP data, a review of current textbooks, and some other analyses of the current situation in K-12 science provided a rich source of data for defining the actual state of K-12 science teaching in the U.S. in the late 1970's (the retrospective synthesis). Various areas of science

education were represented by five "focus" groups which worked on the task from different perspectives. These were the perspectives of biological science, physical science (including the earth sciences), inquiry, science/technology and society, and elementary school science.

One of the first tasks of the project was to identify the basic goals of science education so that one could evaluate its effectiveness. To perform this task, a number of articles and publications discussing goals, rationale or philosophic perspectives in science education were identified. The goals were then sorted into a limited number of goal "clusters" which embodied the primary aims of science education. The goal clusters used were :

- 1 Personal Needs. Science education should prepare individuals to utilize science for improving their own lives and for coping with an increasingly technological world.
- 2 Societal Issues. Science education should produce informed citizens prepared to deal responsibly with science-related societal issues.
- 3 Academic Preparation. Science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate for their needs.
- 4 Career Education/Awareness. Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.

The five focus groups used the four goal clusters as one of several organizers. Conditions were defined which would be expected if the major goals were being met. The focus groups also looked at desired learning outcomes, curriculum features, programme utilization, course offerings and enrolments, teacher characteristics and strategies, and evaluation as components of education requiring definition in terms of desired states.

Prospective Synthesis

The desired state of science teaching was delineated prior to a study of the surveys used to define the actual state. The information consisted of a wide variety of writings and reports concerned with current projects, view-points, research, indicators, needs, issues and futuristic planning.

A major initial task was to develop operational definitions of effective science education. This definition took the form of "desired states" of various elements of the educational process. The "desired states" resulted partly from translation of the goal clusters into descriptions of the conditions one would expect to find if those broad goals were in fact being achieved. Primary attention was given to classes of student outcomes and to curriculum characteristics logically associated with those outcomes. For each focus group, a first step was to define their own area by listing small content domains, or themes, which would become a part of the focus, and then to list student outcomes in each domain which were consistent with the four major goal clusters.

Retrospective Synthesis

In analysing the actual state of science teaching, a major task was to "digest" the available data as completely as possible. Each focus group

spent from seven to ten days of meeting time and at least that much time in homework systematically studying and discussing the information sources identified previously.

Group members studied each of the three NSF-funded reports and National Assessment data relevant to the particular focus of that group. In addition, the Biology, Physical Science, Elementary and Science/Technology/Society groups analyzed widely used texts. Subsequently, discrepancies between "desired" and "actual" states were identified and studied.

RESULTS

Project Synthesis generated voluminous findings and for that reason the sample results reported here will primarily reflect those of the Biology group headed by Paul DeHart Hurd. While results varied somewhat from one focus group to another, there was much consistency in their findings.

The biology focus group believes it has preserved the basic concepts and principles of modern biology as they have emerged from theory and research in its "desired" model. What is different is the educational context in which the biological concepts and principles are displayed. In the desired biology programme biological concepts are organized in terms of personal needs, social issues, and career identification in contrast to biology courses organized in ways to display the structure and logic of biology as a discipline.

The focus group's justification for seeking a new rationale for the teaching of biology stems from recent transitions and new developments. The major shifts in science as an enterprise have been its influence on social process and its close alignment with technology. Science and technology have become the two faces of a single "coin". Recently the biological sciences have been influenced by a number of factors including :

- 1 New theoretical insights (socio-biology);
- 2 New technologies for research (recombinant DNA);
- 3 New interdisciplinary perspectives (biophysics, biochemistry, environmental psychology, human ecology);
- 4 New concerns about biology and human activities (bioethics, human engineering);
- 5 A new awareness that although human beings evolved by means of natural laws, survival is now under control of the human species itself; and,
- 6 New insights into biology as a link between the natural and social sciences giving rise to new cross-disciplinary perspectives (social biology, human ecology, ecological psychology) directed toward comprehending human life as a whole.

The over-arching rationale of the desired biology programme is the use of biological knowledge to enhance the understanding of oneself and to benefit the quality of life and living for human beings. To achieve these purposes requires the study of the human organism in its natural, cultural and psycho-social environments. The desired biology for pre-college students is essentially a science of human beings focused on human adaptation and future perspectives for human welfare. Biology taught for these purposes involves questions of ethics, values, morals and aesthetics.

The objectives of the desired biology programme centre on the study of the human species as a part of nature (1) to understand human beings as a distinctive organism; (2) to appreciate the universal human need to be in touch with our own nature, and all of nature; and (3) to learn to live in harmony with nature and to minimize the dissonance between the social and natural environments. The Biology Focus Group identified examples of specific student outcomes in a variety of biology topics consistent with the four Project Synthesis goal clusters and these are included in the final report.

Discrepancies

The major discrepancies between the actual and desired states of biology lie in the underlying philosophical assumptions. The desired programme is a consideration of biology in a framework of personal and social aspects of human culture. In the actual biology course, subject matter is used to portray the structure of the biological disciplines.

Goals

An effective biology programme utilizes the human being, human potential, human advances, and human adaptation as organizers. Alternative futures will be a desirable focus. Generally, there has been little emphasis upon the human and the human environment in current programmes. A second goal for an effective programme is the utilization of current problems and issues as organizers; currently there is only marginal emphasis upon such goals. A third goal for an effective science programme emphasizes those processes that can be used. In the past, inquiry skills have occasionally been included that emphasized processes that scientists purportedly use. A fourth goal for desired science programmes suggests the importance of practice with decision-making skills involved in using scientific knowledge in a social context. Often the current emphasis in science classrooms is upon uncovering correct answers to discipline-bound problems. A fifth goal for the desired biology programme places emphasis upon career awareness. Such considerations should be an integral part of early learning and not incidental. In current programmes reference to careers when it occurs, is usually limited to highlights concerning persons in history. A sixth goal for a desired science programme involves students in value, ethical, and moral considerations in biosocial problems and issues. Currently science is too often taught as value-free with discipline-bound concepts and activities.

Curriculum

The curriculum should be problem-centred, flexible and culturally as well as scientifically valid. Currently the science curriculum is textbook centred, inflexible, and only valid in a scientific sense. Secondly, the curriculum should include the human as a central ingredient. Currently, humankind is only incidental in the curriculum. There almost seems to be a conscious effort to make science antiseptic, and void of humans. A third feature of a desired curriculum is that it is multifaceted with local and community relevance. Currently, the curriculum is textbook-controlled where local relevance is fortuitous. Fourth, use of the natural environment, community resources, and current concerns should be foci for study. Currently the cook-book study of contrived, classroom-bound resources is almost exclusive. A fifth feature of the desired science curriculum is a view of scientific information that can be used and applied by students in a cultural/social environment. Currently scientific information is presented in a context wherein the logic and structure of the discipline predominate.

Instruction

First of all, instruction in the desired programme should be individualized and personalized, recognizing student diversity. Currently group instruction is the mode and it is geared to the average student and directed by the organization of the textbook. A second feature of desirable instruction is emphasis upon cooperative work on problems and issues. In most science classrooms there is relatively little group work. When group work does occur it often involves verification-type activity in the laboratory. A third feature of a desired instructional mode is that it be based upon current information from the research in developmental psychology. Much current practice arises from weak psychological bases; when there is such a psychological basis it often has a behaviouristic orientation.

Evaluation

Testing and evaluation should stress the use of knowledge to interpret personal and social problems and issues. Currently testing and evaluation are based upon replication of assigned information. Another feature of a desired evaluation programme is its concern for growth in national decision-making strategies. In too many classrooms students are merely expected to state "correct" solutions to preplanned problems.

Teachers

Teachers need to have some specific characteristics for the desired state of science education which has been synthesized. Good teachers will have a commitment to human welfare and progress. Such philosophical perceptions are often not visible in current practice. The primary or only observable commitment on the part of many science teachers is to science as a discipline. The desired programme requires teachers with new philosophical positions since those positions affect goals, curriculum, and teaching practices. Many teachers currently reflect an atheoretical orientation on their curriculum and teaching.

In short, participants in all focus groups in the Synthesis study became convinced of a major mismatch between the practice of science education and the needs of individual students and the democratic society. The educational goals reflected by practice in science education appeared to be extremely narrow and based on the erroneous assumption that most science students will go on to take considerable coursework leading to careers in science. Goals which appear to be largely ignored include preparation for citizen participation in science and technology-related societal issues, preparation to utilize science in everyday life, and preparation for making career choices in science-related fields.

There was a large degree of consensus within and among the focus groups as to the general status of science education. Several generalizations emerged which reflect the conclusions of all focus groups and which are supported by the data base. These generalizations are :

- 1 At all levels, science education in general is given a relatively low priority when compared with the language arts, mathematics and social studies, and its status is declining. This low priority results in a general lack of support for science in most school systems.
- 2 Textbooks play a dominant role in science instruction.

- 3 Of the four goal clusters outlined earlier, only the goals related to development of basic knowledge for academic preparation receive significant emphasis. Goals related to personal use of science in everyday life, to scientific literacy for societal decision-making, and to career planning and decision-making are largely ignored.
- 4 Teachers make most of the important decisions about course content, text selection and instructional methods, and in so doing they determine the goals pursued by science education.

SOME QUESTIONS AND CONCERNS

This section was prepared by V. Lunetta without consultation with the coauthors. It is probable that they have alternative points of view.

The Synthesis project represents a vast amount of labour and creative effort. As a result some provocative and useful models have been developed. Nevertheless, it is highly appropriate to raise a number of questions and concerns about the validity of those models and about the philosophical assumptions underlying the "desired" state. Have the participants in the project properly characterised the nature of the scientific enterprise and the needs of students and the society? Did they objectively pursue a "qualitative/normative" research procedure or did they in fact act out a self-fulfilling prophecy guided by some of their own predispositions and rediscover John Dewey with trappings of the 1980's?

Even objective researchers are certainly shaped by their own world views, and it is important to note that the Synthesis group contained no practising scientists and had only limited direct contact with practising teachers in the public schools. One must ask if liberal science educators (already showing signs of being an endangered species) were off in a corner talking to themselves or if the Project, in fact, synthesized the best recommendations from the evolving young discipline of science education. Their summary notes that teacher decisions about day to day practice rest upon a number of socialization factors not closely related to the goal clusters outlined in the Synthesis report. Were school environment and management realities taken into sufficient consideration in the preparation of the "desired" state or should they remain largely irrelevant to the promulgation of what ought to be? Most important, are there serious biases in the goal clusters that were used as organizers throughout the Synthesis study? Though the disenchantment with science and with science education as it is presently practised is great, is there sufficient justification for a goal cluster framework that removes the discipline of science to one quarter of the whole while advancing personal and societal utility goals to three-quarters of the whole? Are personal and societal goals properly central or should they be more peripheral as conservative scientists will surely claim? Have the Synthesis recommendations gone too far beyond the real demands of the society they purport to represent?

These questions are also related to debates over the role of schools that have persisted for a very long time in a free society. Can the educational system lead or must it follow its society? No matter how one responds to this question, the reality is that when societal demands and the educational system's response are far out of phase, intense funding problems are inevitable.

The Synthesis group believes that the schools are providing a science that is out of phase with the needs of the public and of students. They infer that a

more relevant and personalized curriculum will be more appealing to that society. That inference may be true, but it is among a number of untested assumptions in the Synthesis report. Can societal relationships be emphasized in a meaningful way without giving less emphasis to important opportunities inherent in the natural sciences in which students can manipulate and observe materials within the realities of limited time and management problems that are present in the schools? Developmental learning models (advocated by the Synthesis group) normally imply that student interaction with material objects is an important factor in the enhancement of logical development. If curricula are modified to have the more utilitarian and personalized orientation advocated by the Synthesis group, will sufficient students be prepared with a sufficiently rigorous background in mathematics and science to reach the frontiers of contribution in science and technology that are essential if the society is to develop and survive?

In the curriculum development efforts of the 1960's, the structure of scientific disciplines may well have been over-emphasized to the detriment of societal, personal, and utilitarian goals, but, dedicating three out of four goal clusters for science education to societal and personal concerns may result in over-emphasis of a different kind. Optimally, a proper balance among goals must be found.

Had more diverse science, teacher, and societal interests been represented in the Project Synthesis group, it is probable that their findings would have been more conservative and more consistent with convention and the status quo. That they were a relatively homogenous group enabled them to define a "desired state" that is markedly different from what exists in schools today. As such, the model they have promulgated provides a benchmark for comparison that will be especially useful in efforts to think about goals and to develop curricula for the decade to come.

IMPLICATIONS

A special challenge that emerges is the need to shift goals, programmes and practices from the current overwhelming emphasis on academic preparation for science careers for a few students to an emphasis on preparing all students to grapple successfully with science and technology in their own, everyday lives, as well as to participate knowledgeably in the important science-related decisions their country and the world will have to make in the future. One over-arching responsibility faces every person associated with science education. The responsibility is to rethink the goals of science education in light of basic educational philosophy and the unique role science plays in all of our lives and to redirect the science education system toward those redefined goals. The Synthesis Report goes on to suggest specific curriculum changes that may occur if its recommendations are adopted.

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**PRIMARY SCIENCE, INQUIRY AND CLASSROOM DEMANDS :
PRE-SERVICE TEACHERS RESPONSES AND PERCEPTIONS**

Keith Skamp and Colin Power

INTRODUCTION

Primary science curricula in Australia strongly encourage teachers to plan and select activities which emphasise firsthand experience, inquiry and problem solving. Pre-service institutions, therefore, need to ensure that their graduates are familiar with the "inquiry teaching" concept and the associated teacher and pupil behaviours. However, in attempting to plan and implement "inquiry" methods during practice teaching, preservice students must also seek to "cope" with the demands of the classroom. The demands have been conceptualised by Westbury (1973) and Abrahamson (1974) as:

- Attention: the creation of a learning atmosphere in the interests of task attention and order.
- Affect: the development in children of positive attitudes towards schooling.
- Coverage: the content (knowledge, skills and appreciations appropriate to a curriculum area) the teacher attempts to expose the pupils to in a limited time.
- Mastery: the attempt to ensure that the content has been learnt.

In the usual classroom the teacher develops "coping strategies" enabling them to more or less attend to these demands using the limited available resources (the teacher, curriculum material etc) while at the same time remaining sane. A juxtaposing of inquiry procedures and copying strategies is needed if the goals of inquiry are to be rationalised against the reality of the classroom.

This paper describes the perceptions of inquiry held by five pre-service teachers, the extent to which the pre-service teachers implemented lessons with inquiry characteristics and their perceptions of same; and the degree to which the demands of the classroom were met.

METHOD

Five volunteer pre-service teachers in the second half of their pre-service preparation were interviewed to determine their perceptions of inquiry teaching just prior to a practicum in which one science lesson was taught every week for a minimum of six weeks. Each student was requested to use inquiry-oriented lessons in the practicum. The classes involved were grades 5 and 7. Group sizes ranged between 12 and 20 pupils. Eighteen lessons were observed, three or four lessons for each student. Observation involved taping and compilation of field notes. Further data were gathered by asking all pupils to answer a brief questionnaire based on Browning et al. (1974), collecting samples of pupil work and examining the pre-service teacher's lesson notes. To ascertain the pre-service teachers' perceptions of how they coped with classroom demands and how closely lessons matched their perception of an inquiry-oriented classroom, the pre-service teachers were interviewed immediately following every lesson. Finally, all the pre-service teachers were interviewed at the end of the practicum to determine if their perceptions of inquiry had altered. The supervising teachers were also interviewed to obtain data on context variables.

The participating students had completed all compulsory "education" units and several "curriculum" courses. They were currently enrolled in a primary science unit which covered "areas of inquiry and problem-solving as expressed through the science curriculum". Field experiences had included a gradual introduction to the classroom from term one, and had involved a block practice just prior to the initial interviews. Of the five pre-service teachers, three had entered pre-service education immediately following secondary schooling, and two had gained entry as mature-age students.

RESULTS AND DISCUSSION

1. Perceptions of the Inquiry Approach

All students stated that classes would be pupil-centred with children solving their own problems; the teacher would be more facilitative than directive. Only two mentioned the only agreed characteristic of the approach (Elliott and Adelman, 1974) viz, the "teacher not telling students the generalisations and principles they were intended to learn".

When more structured questions about teacher-pupil, pupil-pupil, pupil-material interactions and organizational decisions were asked the interviewees described the easily observable behaviours associated with the "pupil-centred inquiry-oriented approach" listed by Egglestone and Galton (1976) and Tisher and Power (1975) ie. high levels of pupil participation, the valuing (by the teachers) of supportive personal relationships, adequate teacher-pupil and pupil-pupil communications, and the belief that pupils should have first hand experiences with phenomena. However, no pre-service teachers referred to the specific thought process involved, ie. to infer, devise experiments, test hypotheses etc. (Tisher, 1969, Egglestone and Galton, 1976).

The 'guided' discovery concept - Four of the five students had difficulty in offering any suggestions on this concept. Although one pre-service teacher started to draw a distinction between "guided" and "free" discovery, there certainly was no conceptual framework apparent (cf Elliott and Adelman, 1974) and teacher roles when guidance is employed, were absent. One pre-service teacher mentioned anticipatory planning, ie. forethought given to the likely avenues that investigations might lead to, but generally, the perception that inquiry lessons require detailed planning (see Victor's (1974) first characteristic of inquiry teaching) did not appear to be present. Not one pre-service teacher indicated that inquiry/discovery lessons followed any pattern.

Science and Inquiry - In responding to questions about the emphasis on inquiry in primary science curriculum no links were made by pre-service students between the nature of "inquiry" and the nature of "science". If students had any conceptualisation of the nature of science as a K-6 curriculum subject, it was extremely limited, judging from their responses.

In answer to one open and eleven structured questions on inquiry/discovery teaching, not one pre-service teacher referred to any education authorities as the source of their ideas. Even when directly asked the sources of their perceptions, only two were mentioned, viz. supervising practicum teachers whom the students perceived to be using inquiry methods, and their own observations of children outside college courses judged to be learning about their world by "inquiry". When pressed in the interviews, four interviewees mentioned that one college unit may have influenced their perceptions. Levis et al. (quoted in Hewitson, 1979, p.15) argue with reference to practical teaching skills:

Knowledge (added emphasis) about a particular skills is prerequisite to, but not guarantee of, adequate performance of the skill....

The knowledge associated with inquiry procedures would be expected to derive from, in the first instance, pre-service courses. From the five interviews reported here, this does not appear to be the case. Overall, the pervasive feeling was present that the pre-service teachers' responses were conceptualised on the premise that inquiry teaching is the opposite to direct, traditional teaching.

It appeared that the perceptions held by the pre-service teachers prior to their practicums were limited, and for some of the students, the "inquiry teaching" concept was a nebulous one. Implications appear to be two-fold: either the pre-service teachers will teach as they think they have seen others employ inquiry methods, or they will implement their limited perception of inquiry on a trial and error basis. During the practicum, the latter certainly appeared to be the case.

2. Inquiry and the Practicum Transactions

Lessons were rated as to the extent they displayed the inquiry characteristics included in the "inquiry quotient" scale devised by Lawson et al., (1976). This scale includes twenty-five features which exemplify inquiry teaching: these characteristics were divided into four sub-divisions, viz., the lesson; student behaviour; teacher behaviour and questioning techniques. Four inquiry characteristics were present in most of the 18 lessons (eg. time was allocated for pupil answers or opinions were accepted); twelve in some of the lessons (eg. materials and activities were of interest and provoked thinking, questioning and discussion; pupils were making observations and collecting data); and eight in virtually none of the lessons (eg. pupils formulated and tested hypotheses, pupils analysed, interpreted and evaluated data; concept introduced after direct experiences).

When compared to the pre-service teacher's perceptions of inquiry teaching, the pre-service teacher's lack of differentiation of the thought processes involved in inquiry is evidenced by the lack of encouragement for pupils to use skills such as data interpretations, data evaluation, the testing of hypotheses or predictions; and concept development. None of the students used readily available primary science curriculum projects (such as Science 5/13; Elementary Science Study; and New Zealand Units) which emphasise inquiry. Had they been used, some of inquiry characteristics neglected would have been included in many lessons. Instead the ideas and procedures involved in lessons were literally "off the top of the student's head". In addition, the practicum's organisation did not tend to encourage any follow-through of activities. This meant that the further application of a concept, analysis of data, or even the collecting of data, was overlooked.

3. Perceptions of Practicum Lessons

After every lesson each pre-service teacher was asked:

- a) Would you say your lesson was discovery/inquiry oriented?
- b) What would an observer have noticed to support your assertion?

Three of the students gave no evidence of further clarification of their perceptions over the four week period. When these pre-service teachers thought their lessons were inquiry oriented, they stated their reasons as: "mainly a practical lesson" or "mainly pupil run". The pre-service teachers' uncertainties are shown in such comments as "I'm getting frustrated because I don't know how one lesson could be inquiry or discovery" and "I probably really don't know what discovery/inquiry is"

Of the other pre-service teachers, one was more specific while still not further clarifying reasons over the period, while the other student obviously was prompted by the research project to analyse what she was trying to achieve in inquiry lessons. In the first week, the latter suggested the lesson was inquiry oriented because "the pupils worked their own way through the problem"; she "did not give pupils answers when asked" and had used "open questions"; by week four, she suggested "along the lines of the new curriculum, I set up a situation in which children are required to pose questions; offer hypotheses; try out those hypotheses by data gathering of some form; generalise; (this procedure) has clarified ideas - given a procedure to hang ideas (about inquiry) on".

That for three of the five pre-service teachers, the ability to describe their own lessons as inquiry-oriented remained limited, was borne out in the extended interviews at the conclusion of the practicum. These teachers were unable to alter or addend their answers to the questions in the original interview eight weeks earlier - despite the fact that the students had both just completed a college unit on the science K-6 curriculum which included numerous readings on inquiry and had been specially asked to teach "inquiry-oriented" lessons. The other two students did make changes and additions in their final interview. The most significant additions were: the reference to educational authorities (namely Bruner and Rogers) and more specific detail in relation to a "scientific approach" - one student referred to the scientific method and particular process skills, the other to the syllabus guidelines and process skills.

4. Context of the Practicum Lessons

The supervising teachers were interviewed to determine if, in their opinion, the classroom arrangement and the facilities in the school were supportive of an inquiry atmosphere, and if the pupils were familiar with inquiry techniques. All the supervising teachers interviewed considered that their classes would not be inhibited when using inquiry procedures; however the supervising teachers drew no clear-cut distinction between instruction and inquiry. There is little doubt conditions for coping with the demands of the class and of an inquiry approach could have been improved if the pre-service teachers had discussed their lessons and issues such as room arrangement with the supervising teacher beforehand. This condition was not satisfied in the practicum lessons observed.

5. Inquiry and the Classrooms Demands

Abrahamson (1974) observed experienced teachers and then classified their classroom actions into three levels of decision making, viz. the teacher's basic approach, supplementary manoeuvres and supplementary tactics. These were described as follows:

Basic Approach: As Abrahamson states (p. 63) "there are several classroom procedures in terms of which teachers can formulate their basic approach" such as seat work, recitation, lecture and discussion. If regular teacher behaviours were consistent and aligned with phases of lessons (introduction, demonstration, practice) they were assumed to be a part of the teacher's modal pattern.

Supplementary Manoeuvres: These were regularly used teacher actions, but did not execute one of the three phases of the ideal lesson, e.g. "sense of humour".

Supplementary Tactics: These were either infrequent inclass teacher behaviours or informal personal behaviours that occurred outside the classroom. Supplementary manoeuvres and tactics are actions taken on the teacher's part to overcome deficiencies in the basic approach.

Each classified action by teachers within the above three categories was judged as to its positive, negative or neutral influence on the four demands of the classroom, and consequently, a judgement was made as to the teachers overall "grand strategy". i.e. the teacher's definition of the ends of classroom interactions in terms of the four demands. Four such "grand strategies" for coping have been distinguished by Abrahamson (1974 p. 60).

OMISSION:	ignoring one or more of the four demands
FUDGING ON	
MASTERY:	emphasis on recall only
DEFERENCE	
TO ALL:	equitable distribution of time among the four demands
CONCENTRATION	
ON ONE:	token deference is paid to the remaining three demands.

Although it was originally anticipated that the pre-service teacher's "coping strategies" could be determined, we found it difficult to reliably align teacher actions with effects (positive, negative or neutral) on the classroom demands (e.g., mastery, affect). However, some consistent patterns did emerge.

1) The lesson component "demonstration as summary" (or conclusions to lessons) was non-existent in most pre-service teachers' lessons.

2) If the frequency of teacher actions with positive effects on the classroom demands are totalled, then for two of the pre-service teachers, the grand strategies used could be identified.

Teacher A (4 lessons): Total statements equalled 396. Of these, 175 were rated positive for attention; 122 (coverage); 118 (mastery) and 83 (affect).

Teacher B (3 lessons): Total statements equalled 265. Of these, 176 were rated positive for attention, 177 (coverage); 31 (mastery); and 83 (affect).

From this analysis, it seems that Teacher A tends to give "deference to all", Teacher B has virtually omitted mastery.

Attention: The follow-up interviews and in-class observations indicated that four of the pre-service teachers gained an increasing realisation that this demand exists. However, group management and discipline techniques such as group alertness and accountability (Kounin, 1970) were not consistently employed and, on some occasions, not even attempted.

Of the 18 lessons observed, 15 involved group work, occupying between 17 and 83 percent of the class time (mean 43 percent). Westbury (1973) states that coverage, mastery and attention create coping difficulties when group methods are employed and teachers need to take appropriate steps to ensure that the pupils are kept "on task". Good and Power (1976) suggest that the minimal conditions for children working in groups are high task differentiation, feedback mechanisms and general managerial effectiveness. These factors did not appear to be present on many occasions.

The transcripts indicate that often groups were formed with no previous pre-planned task. It was an on-the-spot decision made at an inappropriate time. The inevitable result was that "academic engaged time" was low and lessons finished "in the air". There was little evidence that pre-service students were helped by their college courses and their supervising teachers to work out how "engaged time" can be maximised in group-based inquiry lessons. Furthermore, supervising teachers rarely discussed the effectiveness of the classroom strategies and manoeuvres used on 'attention' after lesson transactions.

Coverage: In their final interview, the pre-service teachers were asked if they perceived coverage to be a "demand": all responded that they felt little if any "pressure" on them in this regard, yet their lessons invariably included teacher actions interpreted as being aware of the presence of time. The question therefore arises "What are pre-service teachers 'covering' in the practicum lessons"? As indicated earlier, key concepts and generalisations did not constitute any significant part of the observed lessons and there was no evidence in any of the lesson notes that this aspect of "content" was seriously considered. It did appear that the pre-service teachers tended to spend the vast majority of their time "covering an activity" rather than content of a substantive nature. Jackson (1968, p. 162) suggested that

Teachers, particularly in lower grades, seem to be more activity oriented than learning oriented. That is, they commonly decide on a set of activities which they believe will have a desirable outcome, and then focus their energies on achieving and maintaining student involvement in those activities.

When the pre-service teachers taught inquiry science lessons, science content had virtually no influence on their planning or the transactions. Inquiry was synonymous with a "process" but not conceived of as a process used to arrive at a "product". As Suchmann (cited in Kuslan and Stone, 1969, p. 79) warned

Our final conclusion for the present is that inquiry skills cannot be successfully taught to this age group (grade 5) as an isolated content area. The major focus in elementary science education should remain the content rather than the methods of science.

Mastery: When pre-service teachers were asked the post-lesson question "What did the children learn?" they all displayed hesitation. Consider the following answers:

"Well, just the idea of problem-solving. The idea of being put into a situation and having to design things. Yeah, just solving problems, it wasn't really definite learning",

"To the children it was just a game it wasn't learning anything really."

It is clear that the perception that inquiry skills and problem-solving in the absence of content can be taught per se (as suggested under "coverage") exists. In 7 of the 18 lessons observed, more than one third of the pupils felt they had learnt "nothing" or "a little". Jenkins (1966, p. 863) noted

However there may be danger in the contemporary reform that the ability to 'solve problems' may be regarded as more basic than the acquisition of a body of factual knowledge, and even if one accepts the desirability of this order of priority, one still has to question the possibility of teaching with problem solving skill as a main objective.

He went on to suggest:

....critical thinking as generalised ability, can surely only be supported by a discredited faculty psychology.

Focusing on the "mastery demand uncovered other features of the practicum that suggested this aspect of classroom teaching was receiving inadequate attention. Apart from the extensive use of groups which makes 'mastery' a more difficult task for the teacher, it was noted that any recorded work completed by the pupils was not collected by the pre-service teacher and returned with comments. Pupils therefore felt no need to finish written work. Further, science activities were often considered by the pupils to be a break from "work" and different to "learning something". As suggested earlier this may be related to the pre-service teacher's lack of clarity about the key idea for the lesson. A typical example that exemplifies this situation is the type of lesson where pupils are asked to devise an invention, (e.g., a time machine, a rubbish collecting device), but no constraints are placed on the exercise. For a large number of pupils, it becomes a "free-for-all" drawing exercise, not requiring the application of previously studied scientific concepts or ideas. Drawing becomes the end rather than a means to an end. This criticism of the lack of emphasis on mastery of "content" should not be taken to mean that the development of intellectual inquiry skills has no place in science teaching, but rather that much more assistance needs to be given to the pre-service teachers to clarify what is involved. For example, in one lesson the development of "logical thinking" was described as the pre-service teacher's goal. Research by Harlen et al. (1977) and Collis (1977) has indicated the type of detail required if teachers are to have success at assisting pupils towards such goals. Overall, pre-service courses must be specific about the skills and concepts pupils are expected to master in science, and lecturers and supervising teachers must systematically set out to assist the pre-service student in selecting activities and designing and executing lessons accordingly.

Affect: For inquiry to proceed a supportive classroom atmosphere (Harlen, 1977) would appear to be most advantageous. The pre-service teachers all perceived this as their main goal during the practicum, but it was often compromised due to deficiencies in attending to the other three demands. Lessons which were poorly planned and did not provide challenging and substantial content, detracted from pupil affect. The greater freedom in the lessons with the pre-service teachers tended to benefit affect, but the pupil questionnaire data suggests that this diminishes as the weeks progress if the pre-service teacher consistently selects tasks for which pupils cannot see the meaning. Affect is a demand which seems to be better met if there is adequate preparation, a desire to have pupils learn, and the ability to maintain class control. The aspect of preparation deserves special mention. The research (Cohen and Manion, 1977; McFarland, 1973; Talmadge and Rasher, 1979) suggests that all pupils, particularly the brighter pupils, achieve more if the teacher devotes time preparing for instruction. Yet 5 out of 18 lessons were observed where there was almost a complete absence of any overt planning, and on a further six occasions, the lesson notes were of the following quality.

Sample 1: Year 5 (Pre-service Teacher A)

1. Problem Solving: Devise a machine for exercising your dog.
Encourage children to solve problems
2. Classification Skills: Just touch on looking for similarities

Sample 2: Year 5 (Pre-service Teacher B)

Problem Solving:

Aim: To determine how much children already know about this area and develop further what skills they possess.

- 1) Problem solving cards*. In groups of two or three; rotate cards. (Discuss how answers were arrived at)
- 2) Design a machine that would travel into the future.
What would it be like?
What would it need to include?

*Note, These were on pieces of coloured cardboard (four of them measuring about 15 x 5 cm). They bore no relation to science studies, e.g., one card stated
Who is Tom's sister?

"Father, Tom says his uncle's sister is not his aunt".

"Well I expect he is right"

If Tom's uncle's sister is not Tom's aunt, who is he?

Observation of these lessons suggested that this level of lesson planning inevitably leads to a situation in which the teacher is unable to cope adequately with the four demands described, and that pupil centred inquiry is unlikely to be facilitated.

CONCLUSIONS

The pre-service teachers interviewed had initial perceptions of inquiry teaching which fitted the broad descriptions of classrooms described by Egglestone and Galton (1976) and Tisher and Power (1973, 1975). However, they lacked "specific detail" required by the "average teacher" (Tisher et al. 1972, p. 91) for implementation. This was further supported for four of the five teachers in interviews following each lesson; the fifth pre-service teacher did, however, start to refine her perceptions. At the conclusion of the college science curriculum unit, and the practicum, three of the pre-service teachers could not alter their original perceptions of inquiry; the other two students had made changes and additions towards more "specific detail". It is obvious though, that teacher behaviour in inquiry situations, as suggested in the Ford Teaching Project, needs to be emphasised (Skamp, 1981). Without clear perceptions inquiry and discovery teaching will tend to remain "good rallying points for indicating directions and attitudes" only. (Tisher et al., 1972, p. 91).

The classroom transactions coded revealed that classroom relationships (e.g., pupil-pupil interaction) were attempted and encouraged an inquiry atmosphere, but the higher-order inquiry skills and key science concepts and their development, were overlooked. When an analysis of the observed lessons was done in terms of Westbury "coping" framework, all four of the demands suffered in more than three-quarters of the observed lessons in which teachers implemented their perceptions of inquiry teaching. The demands may not have been so affected if more "traditional" lesson planning and teaching procedures had been employed. However, inquiry is recommended in K-6 science by virtually all current curriculum documents. Several suggestions have been

made in this paper as to how pre-service students might be helped to cope more successfully with the "demands" of the classroom in inquiry oriented lessons. The issue of lesson preparation and teacher supervision are but two examples where the situation could be improved.

This study focussed on five volunteer pre-service teachers. It has many quantitative deficiencies and has not the power to generalise. But should the observations and their consequent reflections noted during the study be more widespread, inquiry teaching will have little opportunity of becoming an effective classroom strategy as a consequence of the types of pre-service courses and practicums through which these students had been trained.

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CHILDREN'S DRAWINGS OF NATURAL PHENOMENA

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INTRODUCTION

Modern science programmes for primary schools stress the importance of communication. For example, Science 5/13 (1973) has communication as one of its broad aims,, covering objectives such as Ability to record impressions by making models, painting or drawing.

Although development in the use of these non-verbal means of communicating observations (painting, drawing etc.) has been accepted as an objective, there has been little effort, to our knowledge, to establish criteria by which teachers can note development in this area. Similarly, there has been scant attention paid to providing guidance to teachers as to how to help pupils improve their ability to communicate observations using these non-verbal means.

In one of the few science education texts to deal with the topic (Bird and Diamond, 1975) the authors base their treatment on a 'stages of development model.' These authors quote Kay Melzi as proposing three stages in the development of children's ability to make pictures.

Scribbling. This is more an exercise for the child to gain facility with the pencil or brush. Very little resemblance is discernible between the object and the picture.

Symbolism. The picture is used more as a symbol of the child's idea of the object than to show what it is really like.

Visual realism. There is now a closer and more detailed resemblance between the object and the picture of it.

(Bird and Diamond, 1975, p. 10)

Many authors writing about children's drawing (see, Eisner, 1972) develop concepts to describe the products of children, and, as Melzi has done, from these concepts argue a series of developmental stages. A set of such concepts recently defined by Barrett and Light (1976) seemed appropriate for use in the present study which deals with children from the preparatory grade and grades 1, 2 and 3. These are the concepts of symbolism, intellectual realism and visual realism. Their use, however, does not indicate acceptance of the notion that they represent stages through which a child passes.

Symbolism and Realism

The concepts of symbolism and intellectual realism have a long history but a definitive experiment by Barrett and Light (1976) established three separate categories for discussing the drawings produced by children.

Luquet (1913, 1927) introduced the phrase 'intellectual realism' and this has since been integrated into Piagetian terminology (e.g. Piaget and Inhelder, 1969). Intellectual realism precedes visual realism and is characterised by the child drawing 'what he knows and not what he sees.' There is an ambiguity, however, in the notion of intellectual realism. Is the child drawing what he 'knows' about the individual object, or about its generic type? It seems clear from Burt's work and from more recent studies (e.g. Freeman, 1972) that early representation is stereotypic in character, and equally clear that visual realism requires attention to the individual object. Hence, we should expect two distinct developmental adjustments. Firstly, the child has to move from depicting what he knows of the present individual object. Secondly, he has to move from representing this knowledge of the individual object to representing his visual perspective upon it. There seems no reason to suppose that these two steps should be developmentally synchronous. Consequently, we should expect to find three distinct stages, for which we shall use the terms symbolism (S) in which the child draws what he knows about the genus, intellectual realism (IR) in which he draws what he knows about the individual, and visual realism (VR) in which he draws the individual object as he sees it.

(Barrett and Light, 1976, p. 198)

Children were, as part of the present study, asked to draw two leaves which were put in front of them. Figure 1a shows the way the leaves were presented to the children and Figures 1b, 1c, and 1d show the drawings produced by three of the children. The drawings in Figure 1b exemplify visual realism. The child has represented as best he can what he could see - an oak leaf on the left and, on the right, an elm oriented in the opposite direction. By contrast, the drawings produced by a boy in the preparatory grade (Figure 1c) show symbolism. The drawings of the two leaves are almost identical e.g. Both have a visible stem and an identical shape.

Intellectual realism is shown by the drawings in Figure 1d. Here the pupil drew the elm leaf in the same orientation as the oak. She explained that the elm leaf was attached to the sheet 'upside down'.

These three concepts have obtained a significant place in the thinking of art educators and developmental psychologists and so have been utilised when analysing the data obtained in this study.

METHODOLOGY

Stimulating and Gathering Products

This study used two separate data gathering procedures. The first involved seven government primary schools in the eastern suburbs of Melbourne. The schools were not chosen at random, but were ones with which various members of the research team had established a relationship. The schools covered a broad range of socio-economic areas.

The procedure involved whole classes. In each class one of the authors (JW) took a standard lesson based on observation of four leaves and discussion of the observations made. After this discussion the children drew the leaves.

Four hundred and thirty-two pupils (Preparatory grade - 117, Grade 1 - 142, Grade 2 - 79, Grade 3 - 94) produced 4 drawings each. There was no time limit imposed on the recording task.

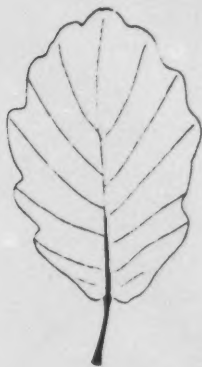


Figure 1a: The oak and elm leaves as mounted on the card and presented to the pupils.

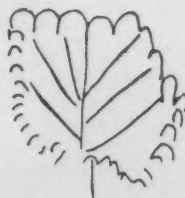
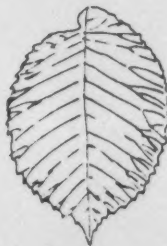


Figure 1b: Drawings of a leaf from an oak and a leaf from an elm which would be categorised as showing visual realism



Figure 1c: Drawings of a leaf from an oak and a leaf from an elm which could be categorised as showing symbolism.

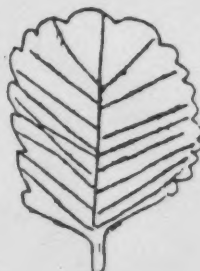


Figure 1d: Drawings of a leaf from an oak and a leaf from an elm which would be categorised as showing intellectual realism.



The leaves used for the lesson, and hence the drawing, were an oak, an elm, a prunus and a eucalypt. Each child was given a card to which the set of leaves were attached, the base of the elm being opposite to that of the other three leaves.

Two differences between the leaves are particularly relevant to the data collection and analyses. The first is that the elm leaf does not appear to have a stem whereas the others have an obvious stem. (The stem of the elm is actually behind the blade of the leaf and so is not seen). The second important difference is that, because of the way in which the leaves were attached to the card and the card was presented to the pupils, the lateral veins of the elm leaf appear to run diagonally downward from the mid-vein to the edge whilst the lateral veins of the other leaves appear to run diagonally upward from the mid-vein to the edge.

The data presented in this paper deal with drawings produced by half of the children in each class. The other half of the children were provided with an outline of the leaves and the children were required to complete the drawing. These data are not dealt with here.

Examining the Process

The second procedure was designed to allow the researchers to observe children from the lower primary grades drawing leaves. Two of the authors (*DS* and *KB*) acted as the observers. Ten children were selected at random from each grade level (Preparatory grade to Grade 3) in a government primary school in the eastern suburbs of Melbourne. The children participated in the procedure one at a time.

A card to which two leaves were attached, a set of coloured pencils and a blank sheet of paper (the same size as the card) were given to the pupil and he/she was asked to draw the leaves. The leaves were an oak and an elm. The elm leaf was fixed so that its base was at the opposite end to the base of the oak (see Figure 1a).

The observer kept a record of the order in which the child drew the various parts of the leaves. After the drawings were completed a structured series of questions was asked and the answers recorded.

RESULTS AND DISCUSSION

The set of analyses to be reported in this paper relate to the question: To what extent are the categories of visual realism, intellectual realism and symbolism useful when considering the ability of children in the lower primary grades to communicate their observations of leaves by drawings?

Table 1 presents an analysis of the data gathered by the first procedure. This analysis shows that almost all of the pupils made an attempt to show different edges on the leaves. That is, this evidence suggests that almost all students saw the task as basically one of producing a realistic product.

TABLE 1

Number (percentage) of pupils who drew all four leaves as having the same edge.

Grade level	Number (percentage) of pupils whose drawings of the 4 leaves all had the same edge
Prep.	2 (2%)
1	3 (2%)
2	1 (1%)
3	0 (0%)
Total	6 (1%)

Further support for accepting that the children generally adopted a 'realism' approach to the task comes from the second procedure where a number of children in the Preparatory grade were very reluctant to start drawing the oak leaf. They said that it was too hard because the edge was so 'wobbly'. The few who did produce obviously symbolic drawings (see, for example, that shown in Figure 1c) attacked the task without hesitation and had the task completed, to their satisfaction, within a minute.

However, although this evidence suggests that the task was perceived by almost all students as one requiring realistic representation, the data presented in Table 2 show that a substantial number of pupils drew a stem on the elm leaf although there was none visible, nor known to be there.

TABLE 2

Number (percentage) of pupils who drew a stem on the elm leaf (although no stem was visible).

Grade level	Number (percentage) of pupils who included a stem in the drawing of the elm leaf
Prep.	47 (40%)
1	45 (32%)
2	22 (28%)
3	21 (22%)
Total	135 (31%)

How can this be explained? For at least some pupils the addition of the stem is a conscious decision as is indicated by the following dialogue between the observer and one of the subjects during the procedure.

- O. (Pointing to drawing of elm). You put a stem on it.
 S. Yes.
 O. Why?
 S. It's better with a stem.
 O. Why is it better with a stem?
 S. They can't go on a tree without a stem.

What of others who included a stem in the drawing of the elm? The evidence suggests that, although they approached the task with a view to preparing a realistic drawing, after a time they stopped referring back to the leaf and lapsed into symbolic representation. There are several sources of evidence to support this interpretation.

First there is the subjective evidence gathered by watching the pupils completing the drawing. Although no measures were taken, the observers both noted that after beginning the drawing many of the pupils made no further observations of the leaf. When, on completion of the drawings, the observer pointed out that the drawing of the elm leaf included a stem, although the actual leaf did not have one, many of the pupils looked embarrassed. One pupil giggled nervously and said 'I forgot'.

Further, there is objective data which lends support to the idea that a significant number of students, although beginning with the intention of producing a realistic representation shifted to relying on memory and so their drawings began to represent the child's concept of 'a leaf' rather than a particular leaf. Such data are shown in Table 3.

TABLE 3

Number of pupils who drew the stem on the leaf by one of three methods.

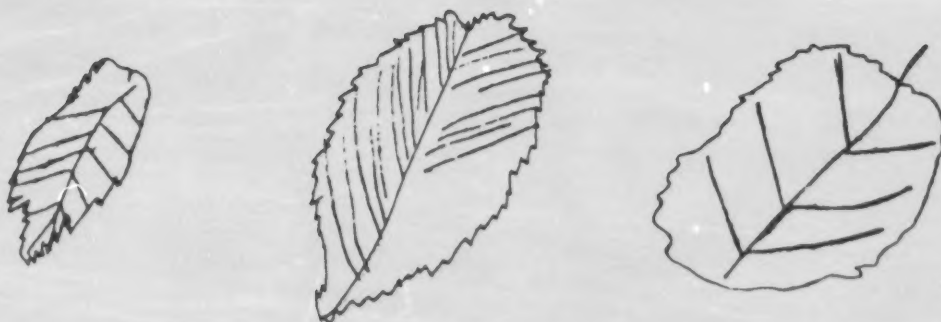
Grade level	Number of pupils who drew the stem by					
	(i) including the stem in the edge		(ii) extending the mid-rib		(iii) adding a separate stem	
	Oak	Elm	Oak	Elm	Oak	Elm
Prep.	0	0	2	0	6	4
1	2	0	2	0	6	2
2	2	0	1	1	7	4
3	2	0	4	0	4	1

Table 3 shows that stems were included in the drawing by one of three methods, viz. including the stem when drawing the edge or outline of the leaf, extending the midrib, and adding on a separate stem. It will be noted that all three methods were used when the pupils drew the oak leaf. However, with one exception, when the stem was added to the elm it was a later addition. These data therefore are believed to support the argument that the stems were added at the stage when the children had shifted from observation to conceptualization.

The questions asked after the drawing showed that at each grade level 8 out of 10 pupils believe that the elm leaf is likely to have a stem when it is attached to the tree. So when the leaf begins to represent conception rather than perception it is likely that stems will be drawn onto the leaf.

Apart from the addition of the stem to the elm leaf there are other analyses of the drawings which add support to this line of argument. These relate to venation. The drawings reproduced in Figure 2 illustrate the issue to be discussed.

Table 4 shows that a substantial number of pupils, although less significant at the grade 3 level, drew the lateral veins (on the drawing of the elm leaf) diagonally upward from the midrib although the elm leaf was placed with the base at the opposite end of the card to the other leaves. In these drawings, therefore, the way these lateral veins were drawn did not show visual realism but indicated either intellectual realism or symbolism.



2(a)

2(b)

2(c)

Figure 2:

Three drawings of the elm leaf. In Figure 2(a) the lateral veins run diagonally downward from the midrib. This represents visual realism. In Figures 2(b) and 2(c) the lateral veins run diagonally upward from the midrib. This does not represent visual realism. It is interesting to note the anomalous placement of venation and stem in Figure 2(c).

Table 4

Of those pupils who drew the venation of the elm leaf in a systematic fashion, the number (percentage) who drew the venation of that leaf

- (i) diagonally upward,
 - (ii) diagonally downward,
- from the midrib.

Grade level	Number (percentage) of pupils who drew the venation			
	(i) diagonally upward		(ii) diagonally downward	
Prep.	32	(62%)	20	(38%)
1	62	(67%)	30	(33%)
2	31	(57%)	23	(43%)
3	25	(31%)	55	(69%)

IN CONCLUSION

The interpretation of data presented here leads to the conclusion that the concepts of symbolism, intellectual realism and visual realism have value in that they point to processes which go on when young children are involved in recording observations of natural phenomena. However the interpretation of the data leads to rejection of the notion that these concepts can be used as an indication of stages of development. It can be noted from Tables 1 and 4 that there are fewer students at grade 3 level whose drawings of the elm leaf contain these features which have been argued may indicate symbolism. But, as has been maintained throughout this paper, many of the drawings represent both visual realism and symbolism. Some pupils began the drawing by observing the leaf, but as time progressed, ceased to refer back to the leaf and began to include features drawn from the conception of leaves. Accordingly, the idea that the concepts of symbolism, visual and intellectual realism are indicators of a series of developmental stages is rejected.

The paper must close on a cautionary note. As was indicated earlier only one natural phenomenon (leaves) was used in this study. This very limited range of phenomena means that care must be taken in extrapolating the findings to a wider range. We do not yet know the results which would be obtained if phenomena which moved were used, or if the phenomena used were more or less familiar to pupils than leaves, or if the phenomena used were 'more 3-dimensional'. Similarly the data were gathered, in procedure 1, after one particular form of stimulus. Would the result be the same if there were, for example, greater opportunities for the pupils to interact with the phenomena being studied? The need for, and some directions for, future research emerge clearly from this study.

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**DESCRIPTION, ANALYSIS AND ACTION:
THREE PHASES OF A RESEARCH PROJECT**

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INTRODUCTION

The Learning in Science Project is a government funded research project investigating science teaching and learning at the 11-14 year old age level in New Zealand schools (see Tasker et al., 1980). The project was organised into three one-year phases:

- | | | | |
|-----|---------------------------------|---|---|
| I | an exploratory phase (1979) | - | to identify problems and difficulties of teaching and learning science. |
| II | an in-depth phase (1980) | - | to investigate some of these problems in depth. |
| III | an action-research phase (1981) | - | to explore ways of overcoming these problems. |

The Project has employed a wide variety of research techniques. In the exploratory phase, naturalistic procedures using unstructured interviews and classroom observations were used. A modified grounded theory approach (Glaser and Strauss, 1967) was adopted for obtaining and analysing data, and the analyses were reported in working papers (LISP, 1979). These papers explored issues raised and enabled findings to be reflected back to teachers and others for comment.

The focus for the in-depth phase of the Project was in children's ideas and thinking, and the influence of classroom experiences on children's cognitive structures or systems. The methods employed were structured interview procedures and more rigorous classroom observations. Where appropriate these naturalistic procedures were supported by a variety of survey techniques. Again a series of working papers (LISP, 1981) enabled findings of this work to be reflected back to teachers and others for comment.

The working papers of the exploratory and in-depth phase also provided a starting point for work on the final action-research phase of the Project. Four groups of researchers and teachers are actively working on finding ways to resolve some of the problems uncovered in the earlier phases of the Project.

In this paper, methodological considerations related to the work of the in-depth phase will be reviewed, some of the outcomes of the work of the in-depth phase will be discussed, the methods being adopted in the action-research phase will be explained, and procedures for disseminating the findings of the Project will be mentioned.

MODELS, METHODS AND PURPOSE - THE IN-DEPTH PHASE

Much of the work of the in-depth phase of the Project was concerned with qualitative description of aspects of children's cognitive structures or systems. West (1980) suggests that such work is influenced by the model of cognitive structures that the researchers hold, the methods used for eliciting

information, and the overall purpose the researchers have. The three concerns of the in-depth phase, namely Children's Science, Children's Classroom Experiences and Children's Outlook on Science (see Tasker et al., 1980) will now be considered from these three points of view.

The work on Children's Science was concerned with children's views of the world and their meanings for words used in science lessons. While no model of cognitive structure was explicitly stated our viewpoint is largely compatible with Gagné and White's (1978) episode-image-proposition-skill model. However our focus is on an individual's existing concepts (an intellectual skill), the relationships that individuals construct for themselves between various concepts, and the importance of the way individuals associate words with these various concepts. In our view a concept results in a measurable 'disposition to act' (Freyberg, 1980) and hence has affective as well as cognitive components. In addition concepts have fuzzy exemplar-non-exemplar boundaries which are context-dependent. Learning new concepts for eliciting information on children's concepts developed out of the earlier work of Osborne and Gilbert (1979) and extended the interview-about-instance approach to include an interview-about-events procedure (Osborne, 1980). The purpose of this work was to provide information on the meanings for words and on the views of the world that children hold so that we might improve the effectiveness of teaching and learning through better communication, for example between teacher and pupil where, without awareness by either party, words may be used by the teacher in a scientific sense and by the pupil in an everyday sense.

Both the methods used and the purpose of the above work led us to confront the difficult task of finding "a method of data reduction, of summarizing the mass of information in a manner which does not distort it, and in combining information in a manner that is meaningful and useful" (West, 1980, p.348). In our work the transcribed interview data from each child were first condensed in such a manner as to preserve the child's viewpoint, whether or not that viewpoint was consistent with the consensus science view or quite different from that view. Next, similar responses by different children to a particular instance or event were grouped together to allow further reduction in data. Draft working papers were then written to portray the most common views held by the 40 or so children interviewed on any particular topic or word. Each paper provided information on the prevalence of certain views amongst those interviewed and provided examples of responses in each category. In some cases, where it was considered appropriate, surveys using larger samples were used to better ascertain the prevalence of certain views at various age levels. Such information was presented within the final working papers (LISP, 1981) and this enabled the description of children's ideas to be validated against the experiences of the teachers, and their previously unformulated knowledge of children's ideas.

The implicit model of cognitive structure behind our work on children's science also influenced our work on Children's Classroom Experience. However, here our concern was with the interactions between children's cognitive structures and the experiences gained in classrooms, particularly where children were doing science. Various aspects of these interactions have been proposed (see Gilbert, Osborne and Fensham, 1981). The methods used to elicit information about the interactions were a combination of individual lesson portrayals using multiple observers, and of modified grounded theory approaches (Tasker, 1980a; Tasker and Osborne, 1980). The central focus of the portrayals were the experiences of individuals and small groups of students working in science classrooms. The in-depth analyses using grounded theory type approaches included observer, pupil and teacher perceptions, as

well as consideration of the implications of these perceptions. The purpose of this work was to portray typical classroom experiences of children in a way that teachers find useful, and to gain insight into factors which lead to pupils retaining particular non-scientific views, or modifying one non-scientific view to another non-scientific view.

Our work on children's Outlook on Science used a model of cognitive systems based on Kelly's (1955) construct theory. This provided a complementary perspective to our other work. The methodology was primarily an in-depth interview approach supported by survey information on the individual's cognitive style, aptitudes, and scientific understandings. Interviews were based on a Kelly Repertory Grid approach (Fransella and Bannister, 1977) modified as advocated by Ravanette (1977). The purpose of this work has been to identify factors which influence children's outlook on science, particularly the differences in outlook between boys and girls as well as between European and other racial groups.

Outcomes of the In-depth Phase

With respect to the Children's Science aspect of the work, over 500 individual half-hour interviews and at least three man-years of full-time research, investigated children's meanings for the words force, friction, gravity, electric current, particles, living, animal, and plant, and children's ideas related to weather, light, physical change and chemical change (LISP, 1981). Some of the results of this work, supported where appropriate by survey methods can be found in Osborne and Gilbert (1980), Stead R. and Osborne (1981a, 1981b), Stead R. (1980a, 1980b, 1981), Stead R. and Osborne (1980) and Osborne (1981a). The central findings from all this work were that young children usually possess meanings for many words used in science and have relatively clear cut views on how and why things behave as they do. However, unlike the scientific viewpoint which is based on 400 years of intellectual endeavour, children's ideas are more superficially pragmatic and self evident, being based on, and largely compatible with, everyday experiences. More importantly some of these views and meanings appear not to be influenced, or to be influenced in unanticipated ways, by science teaching.

Our work on children's classroom experiences, while currently on-going, suggests to us that children's classroom experiences can be portrayed in a way that teachers do find useful and which will influence the way that they teach. In-depth analysis of some 40 lessons, in conjunction with our work on children's science, has already yielded some information on reasons why children's ideas are so often not influenced by classroom experiences in the direction intended by teachers and curriculum writers (Tasker, 1980b). The work on children's outlook on science has revealed the complexity of factors involved. Parental support, cultural background, the image children have of scientists, the perceived usefulness of studying science, the perceived status of science compared to other subjects, all provide influences beyond those provided in the classroom. However, such influences can profoundly affect attitudes, motivation, interest and understanding of science. This work again complements the information obtained from classroom observation.

The findings of all this work raise real and important questions about what science should be taught, to whom science should be taught, and about the place of technology in the science curriculum. Some of these issues are explored in Osborne (1981b) as well as Van Aalst (1980) and Fensham (1980). We are also more aware than before that some of the central issues and problems in the teaching and learning of science lie embedded in the familiar and the mundane rather than in the exceptional and the dramatic. For example

with respect to children's understandings in science, the problems in learning may well lie not in the long technical words or the complex scientific ideas but in the simple words and the simple ideas about how the world behaves. In classrooms, it is teachers' unfounded assumptions with regard to, what has become to them, the familiar and the mundane scientific aspects of a lesson that can create unidentified problems for both pupils and teachers. The wider issues of importance in children's outlook on science may be embedded in values and perceptions which seem so self-evident to the pupil that they can be overlooked even in an interview situation. All this suggests further avenues of research beyond the resources of the present Project.

While we believe our qualitative methods have yielded valuable information, we increasingly appreciate Ravanette's comment (Ravanette, 1977) that the central factor in good qualitative work is the ability of the researcher to know when and how to ask the right question. He, or she, needs to develop the ability to invent better and better questions: questions that are simple for the child to answer rather than difficult, neutral rather than leading, but at the same time penetrating rather than superficial. As mentioned previously there is also the problem of data reduction which we have tried to meet with a time-demanding head-on approach leading to real familiarity with the descriptive data, condensation, some quantitative checks on qualitative categories, working papers and validation involving an external audience.

THE ACTION-RESEARCH PHASE

Work in the action-research phase of the Project cannot possibly address all the issues raised, nor all the content areas considered, in the first two phases of the Project. Based on available resources a decision was made to limit this work to four problem areas each being attacked by a group of researchers and practising teachers. The groups are :

- (a) a physics group - exploring solutions to issues raised in the working papers, force (No. 16), friction (No. 19) and gravity (No. 20).
- (b) a biology group - exploring solutions to issues raised in the working papers, living (No. 15), animals (No. 22) and plants (No. 24).
- (c) a chemistry group - exploring solutions to issues raised in the working papers, particles (No. 18), physical change (No. 25) and chemical change (No. 27).
- (d) an activities group - exploring solutions to issues raised in the working papers, focus on experiments (No. 3), and focus on process skills (No. 7).

Each of the above groups consists of two or three researchers, and approximately seven teachers. The Physics and Activities Groups are focussing on the 13-15 year old age level, the Chemistry Group is concerned with the 11-15 year old age level, while the Biology Group is considering solutions at all possible age levels in the school system (5-17 year olds). The nature of the outcomes from these working groups will depend on the groups themselves. However it is envisaged that practical teacher or pupil guide material of some form will be produced and evaluated.

DISSEMINATION OF THE PROJECT'S FINDINGS

One of the problems of all research projects is the problem of disseminating findings in such a manner that they will eventually have an impact on classroom practice. In addition to the action-research work in the Waikato area, considerable effort is already being made to disseminate the findings of the in-depth phase to a wide variety of interested groups. Working papers have been distributed widely, and shortened versions of some of these papers have already been published. Talks and workshops have been held with groups of science teachers, and with groups of educational researchers throughout New Zealand, as well as at national and international meetings of physicists, science teachers and educational researchers. Some teachers in New Zealand are involved in attempting solutions to some of the problems which we have raised but which are not being considered by our action-research groups, e.g. problems related to the topics of "light" and "electric current". We believe that only by getting a wide acceptance of the problems we have raised, and by arousing an enthusiasm in teachers and others to attempt solutions, will our work have any long lasting effect.

The form of the final outcomes of the Project is, perhaps not surprisingly, still fluid. At present however, we envisage a major report on the methodology and findings of the Project, the publication of reference and resource material for science teachers on children's science and how through classroom experiences these ideas might be modified, as well as exemplar teacher and pupil classroom resource material developed out of the action-research work.

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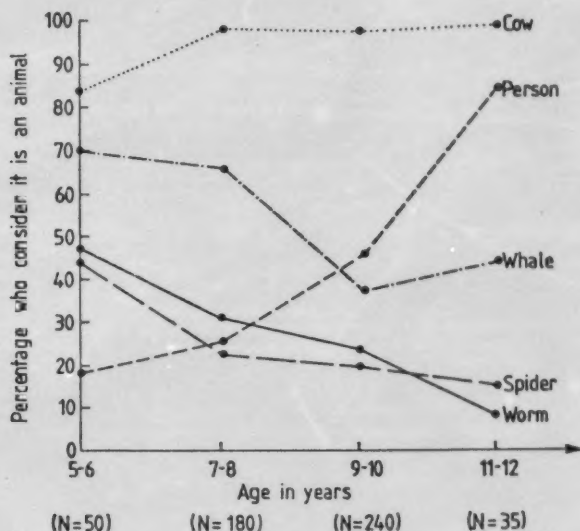
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Appendix A: Children's views on "what is an animal?" A local study.

As part of the work of the action-research phase a number of science teachers and advisers first explored in more depth, how relevant our findings were about Animals, Plants and Living, (Stead, 1980a) at their local level. The following results were obtained at an in-service course where, as a pre-course exercise, teachers were asked to give a simple survey to their children which asked the children whether, or not, each of "a person", "a spider", "a worm", "a cow", and "a whale" is an animal, i.e. Is it an animal? Yes/No. The combined results were,



The results are of interest for a number of reasons. Firstly the children's ideas about exemplars and non-exemplars of animal, and hence their concept of animal, would appear to vary in a complex way over time. It would also appear that aspects of children's concept of animal may well become less like the consensus view of scientists as children pass through the primary school.

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UNSOLVED PROBLEM AREAS IN BIOLOGY : SOME STUDENT AND TEACHER VIEWS

John Dekkers, Alan McLaren and Marvin Druger

INTRODUCTION

Classroom teachers and authorities on education often note that the media have a profound influence on shaping student ideas and opinions. In particular many students spend considerable amounts of time watching television. This has been highlighted in a recent study done by Coulter (1981), who reported on the habits of students watching T.V. Parents, peer groups, teachers and a variety of other factors in the environment also influence learning. In the area of science, Keeves (1979) for example, has described the influences of the home, the school and peer group on students. Whilst many studies have examined the influences of specific environmental components little seems to be known about the raw sources that shape student opinions in and about science. Students need to draw on a variety of sources of information for meaningful learning situations that are new and that may involve problem solving or are inquiry oriented. To be optimally effective teachers need to know about the effects of information sources students use in their learning. This preliminary study was designed to respond to this need by assessing what students and their teachers considered to be the most important unsolved problems in biology and the sources of their opinions.

METHOD

Instruments - Student and Teacher Biology Questionnaires

The questionnaires required the respondent to state, in order of importance, the three most important unsolved problems in biology. In addition, they asked respondents to indicate the main source of information for each of the problem areas they had mentioned, e.g. newspaper, T.V., teacher, text, etc. Administrative procedures for the questionnaire were fully explained to teachers who administered them.

Sample

The instrument was administered to students and teachers of twenty-eight Year 12 Tertiary Admissions Examinations (TAE) Biology classes in the Perth area in July 1980. Among the twenty classes there were three all male student classes and seven female student classes (N = 104 males, 287 females).

ANALYSIS OF DATA

Generation of Problem Area Categories

The first task in the data analysis was to group student responses into unsolved problem categories (hereafter referred to as problem areas). In the generation of general problem areas each different student response was listed once. These responses were then examined independently by the investigators and grouped under single headings which became the problem areas. It should be noted that the investigators were all from quite different backgrounds. They included a teacher of the Web of Life course, a biologist not familiar with the Web of Life course, and a science education lecturer. Each of the investigators generated very similar groupings of the unsolved problems.

Collectively, and after discussions with other science educators and teachers, it was possible to group all student and teacher responses into one of the following fifteen problem areas.

- Adaptation e.g. effects of drugs on man, nutrients of benefit to our body. What gives organisms their colour? why do humans have an appendix?
- Behaviour e.g. abnormal behavior, addiction, communication with plants, misfits in society;
- Biological Processes e.g. enzyme function, kidney function, photosynthesis, respiration, translocation in plants;
- Cells e.g. cell division, differentiation of cells, how cuts heal quickly, function of cellular organelles;
- Classification e.g. plant animal distinction, have we discovered all organisms?
- Diseases e.g. pathological and hereditary diseases, cancer;
- Energy Sources and their Use e.g. alternatives to nuclear energy, radioactivity;
- Evolution e.g. extinction, evolution and origins of man, origin of life and the earth, fossils and fossil dating;
- Genetics e.g. animal and plant breeding, gene action, genetic engineering, use of D.N.A. to benefit man;
- Life Processes e.g. ageing, death, immunology, life force;
- Man and His Environment e.g. biological control of pests, ecological damage, jarrah dieback, man's effect on ecological links, salinity;
- Methods of Biological Investigation e.g. generalising from limited observation, use of electron microscope, why class experiments fail, scientific method.
- Nerves e.g. brain damage, nature of nervous impulse, reconstruction of nervous system function;
- Social Issues e.g. euthanasia, vivisection;
- Population e.g. food production and over population, birth control.

Classification of Responses into Problem Areas

Categorisation of all student and teacher responses was done independently by the investigators. Differences were discussed and consensus of opinion then used when student responses did not clearly fit one of the specified problem areas. For example, a problem arose in deciding whether a behaviour which stated as a behavioural adaptation should be scored in the category Adaptation or Behaviour e.g. bird migration patterns, origins of natural instincts, a biological explanation of man's society. In each of these cases, since the adaptation was a type of behaviour it was scored belonging to the Behaviour category.

Classification of Responses into Questions and Statements

Responses to the questionnaire were classified as either being questions or statements. If there were any "question words" in the response e.g. how, why, what, is there, etc. it was classified as a question, response. All other responses were classified as a statement.

Classification of Responses for Main Sources of Ideas about Unsolved Problems

The following categories of sources were used by respondents: school biology course, film, friend, magazine, media, newspaper, parent, personal, radio, science journal, teacher, tertiary biology readings, tertiary biology studies, textbooks, unknown or no response made. In a number of instances more than one source was provided. In such cases all the data was used. A considerable number of respondents used the term media as a source and hence it was used as such, even though it is a collective term for newspaper, radio and T.V.

RESULTS

Important Unsolved Problem Areas in Biology

In the analysis of the questionnaire data the investigators were able to group all the student responses into fifteen problem areas. Table 1 presents, in order of importance, the derived problem areas based on all student/teacher data together with the % response, type of response made (whether a statement or question) and the sources of information for each problem area. In ranking the problem areas no distinction was made as to whether the problem was listed by students and teachers as the first, second or third most important unsolved problem.

TABLE 1 - Rank order of problem areas for all student data (N=387)

RANK	PROBLEM	1 RESPONSE %	TYPE OF RESPONSE ^b		SOURCES OF INFORMATION ^c			TEACHER %
			STATEMENT	QUESTION	3 MAIN	NON TEACHER	SOURCES%	
1	Evolution	23	34	66	Text(25%)	T.V.(19%)	Teacher(14%)	14
2	Diseases	22	77	22	T.V.(23%)	News(20%)	Text(13%)	8
3	Man & his Envir	15	71	29	T.V.(43%)	News(23%)	Text(17%)	11
4	Behaviour	6	26	74	T.V.(19%)	Text(17%)	Unknown(17%)	6
5	Classification	5	57	44	Text(48%)	Teacher(21%)	T.V.(9%)	21
6	Life Processes	5	22	78	Text(33%)	T.V.(13%)	Unknown(13%)	11
7	Cells	5	36	64	Text(43%)	Teacher(16%)	Unknown(8%)	16
8	Biol Processes	5	40	60	Text(37%)	Teacher(18%)	Pers(10%) T.V.(10%)	18
9	Genetics	4	44	56	Text(28%)	T.V.(17%)	Teacher(17%)	17
10	Population	2	69	31	News(25%)	T.V.(23%)	Text(18%)	11
11	Adaptation	2	36	64	T.V.(20%)	Text(20%)	T.V.(12%) Teacher(12%)	12
12	Energy	2	64	36	News(28%)	T.V.(23%)	Text(13%)	4
13	Tools & Techniques	1	71	29	Text(39%)	Teacher(17%)	Unknown(13%)	17
14	Nerves	1	67	33	Teacher(36%)	Unknown(18%)	-	36
15	Social Issues	0.2	100	-	Pers(67%)	News(33%)	-	0

^a % response is based on total number of student responses for all problem areas (1140 responses)

^b % statement/question is based on total number of student responses for the particular problem area

^c % source is based on the total number of resource responses for the particular problem area

The reason for asking students and teachers to list three unsolved problems was mainly to elicit what they felt were the most important unsolved problems. Asking respondents to list three unsolved problems served as a means to increase the data base for analysis. Three problem areas, Evolution, Diseases and Man and His Environment account for 60% of all responses. Six other problem areas, Behaviour, Classification, Life Processes, Cells, Biological Processes and Genetics, each with approximately 6% response accounted for approximately 30% of all responses. The remaining problem areas (ranked 10-15) accounted for the remaining 10% of all responses. In contrast, Table 2 indicates that for teachers the major unsolved problems were in the area Diseases (33% of teacher responses) then areas Genetics (13%), Evolution (11%) and Behaviour (11%). Whilst problems listed by respondents are represented as problems, it is recognised that these may be a direct reflection of areas of interest.

Table 2 shows that there are no major differences between male and female students and teachers in the rank order and in percentage response for each problem area but some differences occur for type of response. Whilst the teacher data shows a tendency to present the unsolved problems as statements, the students (males and females) tend to present some problems in biology as questions e.g. the problem areas, Evolution, Life Processes, Behaviour and some as statements e.g. problem areas, Diseases, Man and His Environment.

In the analysis of class data for the major unsolved problems it was found that for the different types of classes (all male, all female and mixed) there was relatively uniform agreement regarding unsolved problem areas. However, for the type of response, compared to all male and mixed classes there was a predominance of statement responses in all female classes.

Sources of Problem Areas

Tables 1 and 3 highlight that the text, TV and newspapers are major sources of information of unsolved problems in biology. Table 3 presents the different sources of information used by students and teachers for the problem areas. "Unknown" was used to represent responses where students indicated no source or stated that it was unknown. The main sources of information for students (male and female) and the teachers are in order of the most frequently used source, the textbook, T.V. and newspapers, teacher, then friends. A feature of this data is the similarity between the responses of male and female students. The major difference between the student and teacher data in Table 3 is that teachers used sources such as science journals which were rarely used by students, and tertiary sources which were not at all used by students.

DISCUSSION

All students in the sample were completing studies for the Tertiary Admissions Examination (TAE) Biology course and used as a major text Biological Science - Web of Life (2nd Edn). Also, about approximately one third of these students studied the TAE Human Biology course. In relating this information to student responses it was found that problem areas 5, 11 and 13 could be directly related to the Web of Life course whilst problem areas 10 and 15 are closely associated with the Human Biology course. The remaining problem areas are covered by both courses. With respect to the problem area 'Population' it was found that problems mentioned by students concerned material in the Human Biology course.

TABLE 2 - Ranking of problem areas and type of responses
for student teacher data

PROBLEM	RANK	Female (N = 283)				Male (N = 104)				Teacher (N = 28)		
		RESPONSE ^a %	TYPE OF RESPONSE ^b		RANK	RESPONSE ^a %	TYPE OF RESPONSE ^b		RANK	RESPONSE ^a %	TYPE OF RESPONSE ^b	
			STATEMENT	QUESTION			STATEMENT	QUESTION			STATEMENT	QUESTION
EVOLUTION	1	26	34	65	2	16	33	67	3	11	60	40
DISEASES	2	21	76	24	1	23	80	20	1	33	97	3
MAN & ENVIRON- MENT	3	17	71	29	3	12	72	28	5	8	86	24
CLASSIFICATION	4	6	29	71	9	4	64	36	c	-	-	-
BEHAVIOUR	5	6	29	71	6	7	22	78	3	11	60	40
BIOL PROCESSES	6	4	32	68	8	6	53	47	c	-	-	-
CELL	7	4	27	73	7	7	53	47		/	50	50
LIFE PROCESSES	8	1	21	79	4	8	22	77	6	7	67	53
GENETICS	9	1	44	56	5	7	44	56	2	13	75	25
ADAPTATION	10	2	30	60	14	1	20	80	11	1	100	-
POPULATION	11	2	55	45	10	3	91	9	8	6	100	-
ENERGY	12	2	67	33	11	2	57	43	9	4	75	25
TOOLS & TECH	13	1	58	42	13	1	100	0	c	-	-	-
NERVES	14	1	100	-	12	2	57	43	c	-	-	-
SOCIAL ISSUES	15	1	100	-	15	c	-	-		-	-	-

^a % response is based on total number of teacher responses for all problem area (335 male and 305 female responses)

^b % statement/question is based on the total number of student responses for the particular problem area

^c % problem area not used

TABLE 3 - Student and teacher sources for the fifteen unsolved problem areas in biology

SOURCE	% RESPONSE FOR SOURCE AREAS			
	STUDENTS			TEACHER
	MALE N = 104	FEMALE N = 283	TOTAL N = 387	
Textbook	21	23	22	14
T.V.	19	19	19	12
Newspaper	14	15	14	11
Teacher	12	12	12	4
Friend	11	11	11	10
Parents	4	5	4	6
Media	4	4	4	7
Magazines	3	1	2	2
Films	1	1	1	2
Biology Course	2	1	1	3
Unknown	8	7	8	5
Science Journal	0.3	0.2	0.2	12
Radio	1	0.1	0.3	2
Tertiary Studies	b	b	b	6
Tertiary Reading	b	b	b	6

a % response is calculated on the total number of courses provided for the problem areas. Total response = 531 for males; 1301 for females; 163 for teachers.

b Source not used.

It is inferred from the results that the Web of Life text is serving a significant role in developing student opinions about a number of unsolved problems in biology even though one third of those students had other texts in addition to the Web of Life because they also studied Human Biology. This inference is reinforced by a large number of students indicating the specific use of the Web of Life text as the source of information for an unknown problem.

For the Diseases, Man and His Environment and Population problem areas, TV and newspapers were listed as the major sources of information. Interestingly these three problem areas are not extensively covered in the present TAE Biology course or its major texts. Whilst these problem areas are dealt with in the Human Biology course it appears the TV and newspapers are having a profound effect on developing relevant student opinions in biology. The problems in these three areas often arise in every day situations. It may be that T.V. productions such as Man and Microbes and Life on Earth as mentioned by a number of respondents, are filling a "vacuum" in the education of students. Nevertheless, the total school environment in the study of biology is a major influence in shaping student opinions about unsolved problems in biology. The combination of text and teacher as a source for each of the major problem areas always exceeded 20% of student responses and was as high as 69% for Classification area. Furthermore, it seems that the text and the teacher have influenced student thinking concerning problems associated with

the process of inquiry in biology. Unsolved problems in this area were grouped under 'Methods in Biological Investigation' and although they rank low, student responses may reflect the impact of the inquiry centred approach in the text and teaching strategies used in the Biology course.

The data appear to indicate that students do not use reading sources other than their text in biology. Magazines and journals can typically serve as student enrichment materials for ideas about developments in biology, yet these were rarely mentioned as a source of information. One reason for this could be that the present Web of Life text (2nd Edn) does not require students to read and/or use sources of information other than the text. Perhaps there is a need for teachers to encourage students to use other sources of information and for the text to do so as well. The new edition of the Web of Life (3rd Edn) has an exercise on using the Biology library. Hopefully this will encourage students to read beyond their own text book.

The results for the type of response (question or statement) indicated that a greater percentage of females presented responses to unsolved problem areas as statements, particularly in all female classes. Maybe female students think differently to male students or perhaps it may be inferred that the high occurrence of statement responses can be associated with biology teaching practices that are non-inquiry oriented. The latter inference would be consistent with findings by Dowd and Dekkers (1980). They indicated that the degree of usage of inquiry approaches varies considerably but that this practice mainly occurs at a low level for the majority of classes.

CONCLUDING REMARKS

This study has provided an indication of what students consider to be important unsolved problems in biology and the source of their opinions. This information may be useful in increasing awareness for teachers as to what kinds of problem areas are important to students. The information obtained may be used to redirect emphasis in biology courses. Course changes may include the use of optional learning experiences and other relevant activities that will enrich and extend the variety of experiences currently provided in the classroom. Indeed the use of TV and newspapers as classroom learning resources should enhance learning in biology. However, this study has been confined to biology which is a subject area that is generally acknowledged to have an abundance of media resources. Other science subject areas may not have as many similar resources available and it is in these that the teacher may possibly have to be seen as a more important resource. Further exploration may provide insight on this consideration.

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LEARNING OF PHYSICS AT THE PAPUA NEW GUINEA
UNIVERSITY OF TECHNOLOGY

Beno B. Boeha

INTRODUCTION

It is in the learning of science that one finds the largest number of students requiring guidance and alternative methods of learning. This is particularly true for tertiary students at the commencement of their tertiary courses. For example, many students in Papua New Guinea (PNG) are not sufficiently sure of how to use the library catalogue system and often find it hard to read textbooks because of unfamiliar words and language (Lewis, 1974). As a result, their study methods may not be adequate for coursework requirements.

New students are often not sure how they should best take lecture notes when attempting to summarize the main points from information presented in lectures. Their listening skills may not be sufficiently developed to keep up with and comprehend rapid English dialogue containing new and unfamiliar material. Apart from that, many students also lack confidence in speaking in English (Johnson, 1972).

According to Piaget (1963) and Vygotsky (1962), language is a key element in learning, as thought patterns are expressed through language. In PNG, however, language difficulties and cultural differences are often intertwined. Hence, concepts used by lecturers, instructors or tutors are often not fully understood, especially when idiomatic phrases are used to express ideas (Language Department: UPNG 1977; Johnson, 1972). In addition, a large quantity of course material includes concepts presented in abstract terms which are beyond the experience of many PNG students. Concepts are often not fully understood. This is compounded when academic explanations conflict with traditional explanations of phenomena (BOEHA, 1980). At the end of a course much of what was taught early in the course is forgotten. This problem is magnified in situations like that in PNG where the initial learning of material frequently does not involve understanding.

The above discussion indicates that academic problems do exist which may cause barriers to progress in learning. The academic difficulties are of particular interest to the writer because of his involvement with the teaching of tertiary physics in PNG. For this reason, this study aimed to investigate some aspects of physics knowledge of students.

In particular the study aimed to:

1. test the new students (direct from grade 10) about their learned concepts at the beginning of the engineering courses at PNG University of Technology (UNITECH). A remedial group was formed using their test results.

- 2 carry out a teaching programme to try to improve the remedial group performance on the tests of concepts.
- 3 compare later test performances with earlier test performance of the remedial group.

TESTING AND TREATMENT

Test Development

The diagnostic tests used in this study were the 'Physics Readiness Diagnostic Tests' designed for use in PNG by Mackay (1968). The tests consist of 50 items each.

Test 1 covers the areas of : measurement, position, time, and motion; mass and density; forces and their effects; weight and gravitation; energy; electricity and atomic structure. Test 2 covers the areas of : elements, compounds and mixtures; heat; kinetic molecular theory; light and sound.

Administration and Conduct of Pre-Test

Both tests were administered to a total of 94 students, each taking 60 minutes plus an additional 10 minutes reading time (Group 1).

Formation of Remedial Group

After completion of the tests, the students were classified. Grading of individual students involved summing the individual scores in the two pre-tests. From the ranking, four quartile sub-groups were formed. The third quartile group (scores 36-39) formed the remedial group (Group 2).

Construction of Syllabus for Remedial Teaching

Student comments on the tests, interviews which are not reported here and the results of pre-tests were used to guide the construction of the remedial teaching programme and to develop the section of the syllabus on skills and knowledge for acquisition during remedial instruction. These also helped the writer to select appropriate teaching procedures, together with teaching aids and equipment.

Remedial Teaching

The remedial teaching commenced in the third week, after the completion of the testing programme and the selection of the remedial group.

The materials and resources used for teaching are not detailed because of the great variety. Films and slides could not be included because of their local scarcity. Short questions and exercises were used as checking devices at the end of each topic to determine whether or not students had achieved the objectives. The remedial programme occupied one hour per day for four days per week.

Post-Test

Upon completion of remedial teaching, covering topics involved, post-tests were administered to the remedial group. The procedures for administration of both Post-test 1 and 2 were identical to those in pre-testing.

University Semester Results

The UNITECH physics results at the end of first and second semester were taken from either the Physics Department or the UNITECH student records office.

RESULTS AND DISCUSSION

Reliability of Tests Used

The tests used in this study had reliabilities of 0.75 for test 1 and 0.79 for test 2 (Mackay, 1968). The groups tested were from a similar population to those used by Mackay (1968), and similar reliabilities were expected. As the combined score from test 1 and 2 was used to rank group 1 students, it is the reliability of these combined tests which is of interest here. This reliability (K-R20) was 0.50.

Item Facility for Pre-tests

The calculation of item facilities was taken so as to identify difficult items. The item facilities for both tests can be seen in detail elsewhere (BOEHA, 1980).

There were 20 items which were done poorly by students (i.e. answered correctly by less than 30% of students in each group). Some of the difficulties and misconceptions identified in this study are as follows:

1. Students did not understand and appreciate the fact that the instantaneous speed can vary from the average speed for a travelling body (item 14).
2. Students had serious misconceptions and deficiencies in their ideas on the conservation of mass, weight, density and volume (item 17).
3. Students' ideas of addition and subtraction and colinear and non-linear force were deficient (item 23).
4. Students did not understand and were confused between electrostatic and magnetic phenomena (item 49).
5. Students did not recognize that molecules of the same compound were identical (item 54).

Student Comments

Students' comments from group 1 were classified into a number of types and frequency with which these comments were made (Table 1).

TABLE 1 - Frequency of Types of Comments given by Group 1

TYPES OF COMMENTS	FREQUENCY OF GROUP ONE
0. No comment given	13
1. "Beyond my comprehension"	9
2. Some topic on test which had not been taught	11
3. Questions too long	19
4. Wanted revision time before test	11
5. Appreciate doing test	2
6. Did not understand diagrams	2
7. Other language problems	27

The most common type of comment concerned language difficulties. Comment type number 3 was the next most common; 19 students responded. These students considered that the length of the tests led them to state that 'some questions were difficult'. Comments of the second type indicated that, some questions had not been learnt in high school raising the possibility that some students had not been taught some concepts on the school syllabus. Other comments indicated that the distractors employed in the tests were effective.

Remedial Group Performances

The post tests were administered to the remedial students at the end of the remedial teaching of topics supposed to be covered in each test. The results are shown in Table 2.

TABLE 2 - Mean Score and Standard Deviation Obtained in and Post Tests (Remedial Group) and number of students

GROUP AND QUARTILE	MEAN SCORE		STANDARD DEV.		NO. OF STUDENTS	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
GROUP 1	19.7	20.3	4.3	4.3	94	94
QUARTILE 1	24.2	23.8	1.20	1.30	25	25
QUARTILE 2	20.0	19.9	0.68	0.70	25	25
QUARTILE 3	19.2	18.7	0.49	0.55	23	23
(GROUP 2)						
QUARTILE 4	16.1	15.8	1.21	1.55	21	21
POST-TEST						
QUARTILE 3	25.9	25.0	3.70	4.80	22	22

One of the basic purposes of this study was to see if appropriate remedial instruction could lift the performance of the third quartile of students. It is clear that this has been achieved. The mean performances of the remedial group on post-instruction tests was greater than the mean of the first quartile of group 1 students on the pretest (Table 2). When distributions of scores are considered, it is found that the distribution of post-test remedial group scores has changed considerably by comparison with the pretest distribution of this group. Only one of the 22 remedial group students achieved post-test scores in the range of the scores on the pretest for this group (Table 3).

Scores equal to or better than the range obtained by the first quartile on the pretest were achieved by 18 of the 22 remedial group students. These figures indicated that the performance of the remedial group was changed substantially after the remedial instruction. The strongest indication of the extent to which the remedial teaching programme has had an effect is demonstrated by the distribution of pretest and post-test scores.

All but one of the students in the remedial group mean had pretest performances at or above the level of second quartile group on the pretest. Table 2 shows that, after remedial instruction, the remedial group mean scores on the tests had been raised considerably above the mean performance of the second quartile group on the pretest. This improvement in performance is illustrated more clearly by comparing the frequency distributions of all students on the pretest and of the remedial group on the post-test (Table 3).

TABLE 3 Comparison of Distribution of Scores for all Groups on the Pre-test with the Remedial Group on the Post-test

PRETEST RESULTS FOR ALL QUARTILE			POST-TEST RESULT FOR REMEDIAL GROUP		
Range of Total Score	Freq. Dist.	Freq. as %	Range of Total Score (T1&T2)	Freq. Dist.	Freq. as %
			65-56	6	27
55-45	25	27	55-45	12	55
44-40	25	27	44-40	3	14
39-36	23	24	39-36	1	4
35-21	21	22	35-21	0	0

Semester Results and Discussion

The assessment given to students in physics at the end of each semester was derived from continuous assessment and from performance on end-of-semester examinations. The results of all quartiles for both first and second semesters are given in Table 4.

TABLE 4 Mean Scores and Standard Deviation for both Semesters obtained by Quartiles and Number of Students

QUARTILE	NO. OF STUDS. IN ORIGINAL QUARTILE	SEMESTER 1			SEMESTER 2		
		MEAN SCORE	STD. DEV.	NO. OF STUDS.	MEAN SCORE	STD. DEV.	NO. OF STUDS.
1	25	64	4.5	21	63	4.2	20
2	25	64	3.1	22	60	4.4	19
3	23	66	2.0	22	63	2.5	20
4	21	62	4.6	19	62	4.5	13

The results obtained by each quartile group at the end of the first semester in general show the patterns expected. The fourth quartile had the lowest mean achievement, and the remedial group had the highest. The performance of the third quartile in both semesters suggests that the remedial teaching has been valuable with regard to learning during the first year physics course at UNITECH.

At the end of the first semester, there were not great difference in absolute terms between the other quartiles and the remedial group. However, the semester 1 scores for each quartile were not widely distributed as indicated by standard deviations in Table 4 and the remedial group was one standard deviation higher than the mean of the next group.

On the end of second semester results, the third quartile students again performed well. The third and first quartile had similar mean scores. It is interesting to note that the fourth quartile had a greater mean performance than the second.

The semester results indicated that the remedial instruction given to the third quartile improved their performances on the post-test results. Using another criterion, the semester results also show that the remedial instruction has used effective teaching strategies. These results might be due to the linking of new information with existing knowledge in the way described by White (1977). The semester results also indicate that the remedial instruction was probably having the effect of reducing the drop-out rate.

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IMPLEMENTATION OF A PERSONALIZED SYSTEM OF INSTRUCTION IN
PHYSICAL SCIENCE AND COMPARISON OF ATTITUDE AND ACHIEVEMENT
WITH CONVENTIONAL CLASSES

Ron Cullen

JUSTIFICATION OF PROJECT

The literature on the personalized system of instruction (PSI), more commonly known as the Keller plan is voluminous. It may be thought that further investigation into such a scheme can only re-iterate what is already known. Keller (1968) revealed that students rated his personalized course very favourably. Similar comments have been made by Born and Herbert (1971), Leo (1973) and Vandenbroucke (1975). Green (1971) reported that students greatly enjoyed self-pacing and the opportunity to study when and where they wished. In addition to those, Austin and Gilbert (1973) found that students valued the availability of individual help. Taylor (1975) indicated that most students reported increased understanding of basic concepts, while two-thirds of the students felt that their study habits improved during the PSI course. However, an analysis of the literature reveals that rarely do these studies involve comparison between experimental and control classes. In some cases comparisons have been made between PSI courses and conventional courses. Hoberock, Koen et al (1972) reviewed student attitudes in four engineering courses. Over 70 percent of all students preferred the PSI approach, some were neutral, a small percentage preferred conventional methods.

PSI articles published in Australia include those of Widden (1973), Avey and Northcott (1975), Collins (1975), Burr (1977), Donovan and Northcott (1977) and Findlay and Lark (1978). Of these, only Burr compared experimental and control classes and his survey related to attitudes only. Thus, a comparison of both attitude and achievement between PSI and conventional classes in Australia is relatively novel. The project that was implemented could best be described as a modified Keller plan. Modifications to the basic Keller plan included :

- a a mastery level of 80 rather than 100 per cent.
- b faculty rather than student proctors.
- c a weekly tutorial on a relevant topic rather than a peripheral motivational lecture.
- d a compulsory final examination.
- e a stated percentage for each unit mastered rather than a grade for completion or partial completion of course.

THE PROJECT

Experimental Design

The experimental design selected could be described as a two group pre-test post-test design:

	Pre-Test	Treatment	Post-Test
Experimental Group	O ₁	X ₁	O ₂
Control Group	O ₃	X ₂	O ₄

This choice influenced the type of population sought for the project.

Project Population

Students selected for the project were enrolled in the first year of the Diploma of Teaching (Primary) at Mount Gravatt College of Advanced Education in 1977 and 1978. All had previously undertaken study in biology over four semesters at Secondary school, but no other senior science. Entry to College was determined by the students' ranking on Tertiary Entrance Score (T.E. Score). Students were randomly assigned to classes after matching pairs of students with equivalent T.E. scores and biology ratings. In semester 2, 1977, matching was in threes, as there were two experimental classes. There were 82 students in the experimental population and 60 in the control population. Students were not informed of the basis of their selection.

Operation of Project

In each semester the author was responsible for conducting the Keller class, while another lecturer conducted the control class. Variation in quality of instruction is usually controlled by assigning the same instructor to experimental and control classes. Time-tabling difficulties prevented this in this project. However, as Silberman and Parker (1974) have remarked, it is difficult for an instructor taking both experimental and control classes not to at least unconsciously favour the experimental class. In this project both instructors had previously taught the Physical Science course in the conventional format. The close relationship between previous results on groups that were randomly assigned suggested that the instructors were about equivalent in their teaching of physical science.

ACHIEVEMENT RATINGS, ANALYSIS AND DISCUSSION

Record files of each student provided information on his/her:

- a Tertiary Entrance Score (TES)
- b Aggregate Biology Rating (ABR)
- c Understanding in Science Test Score (UIST)
- d Physical Science Achievement Test 1 Score (PSAT1).

The Physical Science Achievement Test 2 (PSAT2) was used as the criterion for achievement in the course.

Physical Science Achievement Test 1 (PSAT1)

This test comprising 30 multiple-choice items was administered to all students after a period in which all students were taught in a conventional manner. The topics included kinematics, force, work, energy, power and friction. These topics were not included in the major project. All items were evaluated by faculty members who had experience with this class. The reliability of the test was determined by the split-half technique to be 0.832.

It was anticipated that since students had been randomly assigned to teaching groups after matching of (a) and (b), their measures on these scores would be equivalent. However, some attrition of students occurred during the project. A comparison of the two groups revealed the following data:

TABLE 1 - Comparative Data

Variables	Experimental Class		Control Class	
	Mean	S.D.	Mean	S.D.
TES	894.77	35.01	901.42	35.26
ABR	18.97	3.05	18.20	2.96
UIST	21.35	4.00	22.77	4.56
PSAT1	19.88	2.97	21.75	3.95
PSAT2	23.61	6.58	21.72	6.00

In view of the variations between the classes, it was decided to analyse achievement by use of the SPSS Sub-Program ANOVA using the predictors as covariates.

Physical Science Achievement Test 2

This test was administered to both experimental and control classes at the conclusion of their period of study. The test consisted of forty questions, the first thirty being multiple choice, and the final ten questions requiring written calculations. The first fifteen multiple choice questions were drawn from the first six of the twelve units and were evaluated separately to test the comparative effectiveness of short-term retention. The split-half reliability of the test was found to be 0.914.

The result of ANOVA analysis is shown in Table 2. It can be seen that the variation of covariates was significant. It should be noted that the variation due to ABR favoured the experimental group while the variation due to PSAT1 favoured the control group. Controlling this variation enabled a more meaningful assessment of achievement on the criterion test.

The use of ANOVA techniques has been the subject of considerable discussion. The interpretation of ANOVA results is questionable unless students have been randomly assigned to treatments. It is contended that the assignment of subjects in this subject was essentially random. Thus the calculated F values in this project merit cautious acceptance.

TABLE 2 Analysis of Variance
Dependent Variable - Physical Science Achievement Test 2

Source of Variation	Sum of Squares	D.F.	Mean Square	F	Significance
Covariates	2173.6	4	543.4	22.2	.001
TES	13.5	1	13.5	.6	.999
ABR	674.2	1	674.2	27.5	.001
UIST	3.8	1	3.8	.2	.999
PSAT1	540.1	1	540.1	22.0	.001
Main Effects	244.1	1	244.1	9.9	.002
Residual	3336.2	136	24.4		
Total	5753.9	141	40.8		

Similar ANOVA analyses were carried out using parts of PSAT2 to test short term retention and ability to perform mathematical calculations. F values of 10.0 and 16.5 were obtained (DF = 141).

The achievement of the experimental population was significantly greater than the control population with respect to overall achievement (which includes short-term retention and ability to perform mathematical calculations). These findings are consistent with those reported by Austin and Gilbert (1973).

Part of the success of PSI students seems due to the fact that they work harder. Given a course contract which specifies exactly what can be attained, students tend to strive for the maximum. It is a novel experience to be requested by students to allow them the privilege of working outside scheduled hours so that they can keep pace with the course.

Course Attitudes

Attitudes to the course were assessed by the use of an instrument (Physical Science Course Survey) consisting of twenty items based on an instrument devised by Silberman and Parker (1974) to assess student attitudes to a Keller plan (PSI) in organic chemistry. An equivalent number of positive and negative statements were included.

The instrument allowed four responses which were scored from 4 representing a very positive attitude to 1 representing a very negative attitude. The mean value for a neutral attitude was thus 2.5. The results for each class are tabulated on Table 3. The experimental class recorded a mean result over twenty questions of 2.93 and the conventional class scored 2.82. It was observed that overall, both groups of students held positive attitudes to the course.

The seven items that displayed large differences in means were:

1. The method of instruction in this course made allowances for individual differences.
2. The objectives of this course were not made clear to me.
3. Taking this physical science course has increased my sense of responsibility for my own learning.
4. This physical science course provided more personal attention than I generally receive in a class of this size.
5. The method of instruction in this physical science course is an effective way to teach physical science.
6. This course in physical science allowed greater access to the lecturer than other methods.
7. This course made me adopt study habits that were more regular than required for other courses.

A comparison of the mean values of the statements between the groups revealed differences of 0.40 for statements 1, 2, 5, 11, 14, 19 and 20

TABLE 3 Physical Science Survey - Comparative Data

Statement No.	Experimental Group Mean	Control Group Mean	Difference
1	1.93	2.53	+0.60
2	1.78	2.18	+0.40
5	2.00	2.68	+0.68
11	1.94	2.40	+0.46
14	2.27	1.82	-0.45
19	1.82	2.35	+0.53
20	1.78	3.02	+1.24
Aggregate Mean	41.47	43.57	+2.10

The survey revealed that the experimental population perceived more strongly than the control population the features of individualized classes such as: clear objectives; greater access to the lecturer; personal attention, self responsibility, allowance for individual differences and the need for regular sustained study. These results were not unexpected.

It is to be noted that the control population gained slightly more enjoyment from the course, were more likely to recommend it to friends, and felt more strongly that all courses should be taught in this manner. These comments were not anticipated. I believe that the experimental population found the unit tests caused them to feel they were required to make a much greater effort than the control population. The survey was taken concurrently with the criterion test so that the experimental population was not completely sure that their increased effort had in fact produced higher grades. This may have reduced their feeling of enjoyment of the course.

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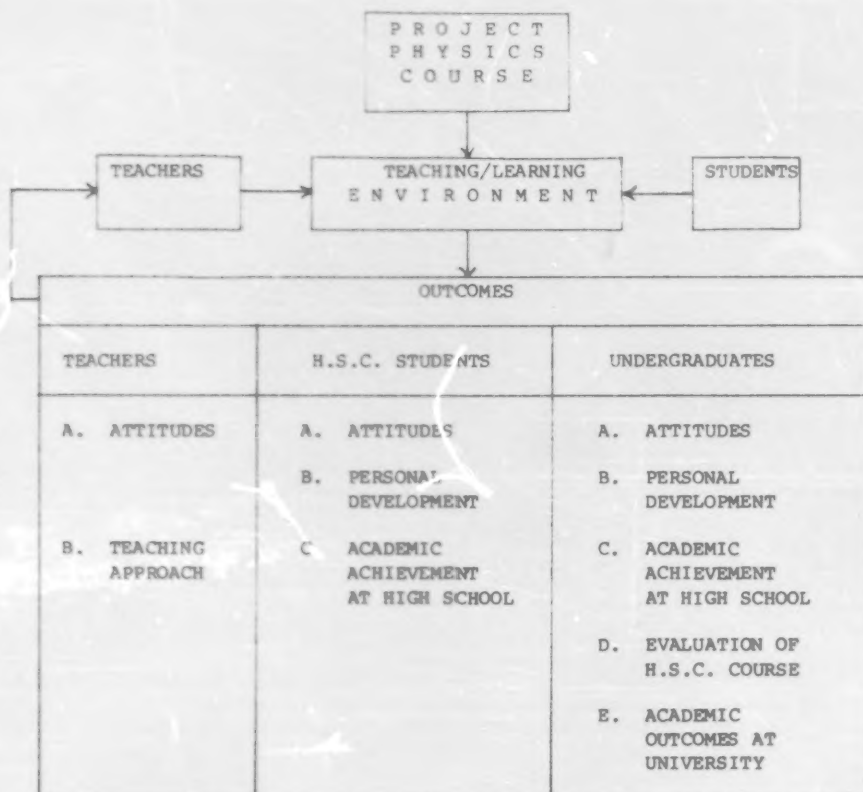
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PROJECT PHYSICS IN N.S.W.

Cyril Quinlan

Central to the study was a description of the teaching/learning environments in a sample of physics classrooms. Such a description was obtained from the students in the classrooms, using a written survey method. Three influences on the environments were considered - the Project Physics Course itself, the teachers and the students. These three influences met in the physics classrooms. Outcomes were also studied for the teachers and for the students - both a small group of First Year undergraduates and a larger group of Year Twelve students who were preparing for their final high school examinations leading to their Higher School Certificate (H.S.C.) See Figure One for a schematic summary of the scope of the research and Holton (1978) for details of the development of Project Physics.

Figure 1. Schematic Summary of the Scope of the Research



In 1970 three N.S.W. schools completed some pre-trialling and the following year thirty-four N.S.W. schools started trialling - books and equipment supplied. At the end of the two-year course students sat for special physics examination marked "Trial Physics" as part of their H.S.C. examinations. This system continued for the next few years. In 1972 the N.S.W. Science Evaluation Committee issued two reports on the science courses being trialled. These reports reflected strong support by teachers and students for the "new" physics. By 1974 there were 165 schools trialling Project Physics in N.S.W. In 1975 a new physics syllabus came into force across the State. No texts or materials were prescribed by the syllabus. However, many schools adopted the Project Physics Course as a suitable approach for the requirements of the new syllabus. The first H.S.C. examination on this new syllabus was in 1976.

In 1977 research data were collected from Year Twelve physics students and their teachers and the following year additional data were obtained from undergraduates at Macquarie University. Collecting data just two years after the introduction of the new physics syllabus proved to be ideal for the purposes of this research.

The research kept several characteristics of Project Physics in focus. Many of these characteristics derived from the intention of the authors to plan for "the preservation and exploitation of individual differences both in teachers and students" (Holton, 1967: p.210).

The Course provides a multi-media approach to physics with materials such as text books with in-built self-assessment questions plus application problems and discussion questions, laboratory experiments and associated handbooks, programmed learning booklets, 8 mm film loops, overhead projection transparencies, which were produced as slides for Australia, and Readers to accompany each of the six units of texts.

Within the laboratory handbooks several experimental approaches are often given for the one area of investigation - for instance, half a dozen methods are outlined for measuring the acceleration due to gravity. With such an array of suggestions and materials, teachers, perhaps for the first time in their teaching careers, were deliberately encouraged to make choices from amongst an accessible set of alternatives. One option open to the teachers was to use the student-centred method which allowed students to make choices - to share in the decision-making process opened up by Project Physics and, in this way, to share the responsibility for their own progress.

The authors of Project Physics saw the Course as teacher-centred from the point of view that teachers could choose from a variety of teaching styles, ranging from the chalk-and-talk method to use of the multi-media system and an independent learning approach which included self-pacing.

The laboratory handbooks were incorporated into the student texts and cross-referencing between text and handbook was frequent, emphasizing the integration of theory and practical work.

Project Physics also sets out to present physics as part of a human adventure rather than a collection of facts and formulas. Holton, one of the three directors of the Course, referred to this humanistic conception as "really the heart of the program" (Holton, 1978: p.290).

PROCEDURES

The sample sizes were as follows: 38 schools, 59 teachers, 46 classes, 740 H.S.C. students, 143 undergraduates. Practically all analyses of H.S.C. data took the class as the unit of analysis. Twenty-eight of the teachers had taught senior physics for three years or more, and comparisons of new and old syllabuses were analysed only for these 28 "experienced" teachers. Data from academic records were obtained on all 143 undergraduates enrolled in First Year physics courses at Macquarie University at the start of 1978. Over 40% of these had not studied physics at high school and so the undergraduate survey was irrelevant for them. Analyses were possible on returns from 49 undergraduate surveys.

Three environment scales were established. The Emphasis on Experiments Scale scores showed that moderate to little emphasis was reported by most classes while about a third of the classes had stronger emphases on experiments. From the mean class scores on the Role of Experiments Scale it was clear that in most classes experiments and theory were fairly well integrated. The Student Autonomy Scale scores showed that students recorded large differences between classes as regards their view of the amount of freedom their teachers allowed them. Generally they regarded this as fairly low. It is interesting to note that teachers rated themselves better on this aspect, reporting themselves to be generally in favour of student autonomy.

With these three scales the differences between the forty-six classes were readily identifiable. The classroom sample included classes taught by a whole spectrum of teaching methods, even though all classes were studying the same syllabus and 72% of them were using Project Physics texts. These results support the comment made by MacKay after studying the P.S.S.C. physics course in three Australian States: "... there exist as many different variations on a physics course as there exist teachers" (MacKay, 1971: p.116).

A multi-dimensional profile of each classroom environment was preserved during the analyses used in the present research, and correlational techniques were used throughout. This research method is in contrast to one often found in education research, in which teaching approaches are categorized by a simple "Yes" or "No" - Project Physics or non-Project Physics. In terms of standardized scores, nine of the classes in the sample had positive and reasonably high z-scores on each of the three environment scales. These were at the Project Physics end of the continuum on each scale. At the non-Project Physics end there were eleven classes with reasonably sized negative z-scores on each scale, and the remaining classes had other blends of characteristics.

Apart from the three scale scores, other item scores gave useful information regarding multi-media methods, teacher-controlled organization and humanitarian aspects.

In general, the classes studied tended to be "traditional". Nevertheless, there was considerable evidence the "newer" teaching methods were being used, at least in some cases: Multi-media techniques (such as photography, film loops, slides, programmed learning books, availability of experiments) were evident; teachers were coping with a variety of activities during a physics lesson; students were being given some choices and responsibility; the history and social relevance of physics were being treated, and so on. These things were happening despite the fact that the lecture/discussion type of lesson was the most common: According to more than half of the H.S.C. students surveyed, the teacher "Very Frequently" taught the class as a whole for more than half the period.

RESULTS AND DISCUSSION

One of the main interests was to find out the effects on teachers of the experience of teaching physics in the spirit of Project Physics. The research data showed that the more fully the teachers entered into the spirit of Project Physics the more they tended to like it and the more their perspectives on teaching tended to change. For example, teachers who recorded more change towards favouring student autonomy and personal development of the students tended to have classrooms in which more student autonomy was evident, implying that after giving students some decision-making and responsibility, teachers tended to like the outcomes.

Teachers were asked to record their level of agreement or disagreement with a series of statements about physics teaching. They were asked to record both their "Present" Opinion and their "Prior" Opinion - the "Present" Opinion was their opinion at the time of completing the survey; their "Prior" Opinion was what they recalled as their opinion prior to teaching the then current physics course. Four teacher opinion scales were formed and on each of these a change in opinion was reported which was statistically significant and in the direction favourable to attitudes encouraged by Project Physics. See Table 1 for details.

TABLE 1

Analyses of Changes in Opinions of Experienced Teachers
Using Average Scores per Item for Opinion Scales (N=28)

Prior Mean*	Present Mean *	Mean Difference	t-value	2-tail significance
<u>Attitude to Experimental Approach</u>				
3.92	4.25	0.33	2.23	0.034
<u>Attitude to Student Autonomy</u>				
2.54	3.39	0.85	4.37	< 0.001
<u>Attitude to Personal Development of Students</u>				
3.48	4.10	0.62	5.02	< 0.001
<u>Attitude to Humanitarian Approach</u>				
3.41	4.15	0.74	6.20	< 0.001
* Items scored so that higher means denoted more favourable attitudes.				

There are two pieces of indirect evidence that Project Physics could have contributed to such change: apart from the fact that they were registered as occurring during the period of teaching the new course. First, the amount of Inservice on Project Physics was related to some of the aspects of change regarding Personal Development of the Students - teachers who attended more Inservice tended to record more change. Second, teachers who used the Project Physics Teacher Resource Books showed more positive change towards the humanitarian approach.

More direct evidence came from the analysis of responses to one general question which tried to get to the cause of changes in opinion. It read: "Project Physics has been the major cause of the changes in opinion noted above."

Although changes for items on three of the opinion scales correlated significantly and positively with responses to this general question, regression analysis highlighted changes on only one item as accounted for by Project Physics. It was the item: "A major part of Physics teaching time should be spent teaching the class as a whole."

The teachers recorded an average change from agreeing with this statement to disagreeing with it, and it would seem that Project Physics was a major cause of this movement by teachers away from centre stage in the classroom.

It was noted that those who had taught senior physics for a longer time tended to change opinions less than the others. Also, teacher satisfaction with the way they taught physics was found to be associated with support for student autonomy and with having some physics periods in a room other than the laboratory.

The research showed that positive student outcomes tended to be closely associated with low levels of frustration. This can be seen from the negative correlations listed in Table 2. The measure of frustration used here was the degree of agreement or disagreement with the statement: "During the Course, I often felt frustrated trying to find accurate information on the facts and principles of physics."

In their survey responses, both high school students and undergraduates acknowledged that personal development benefits had been associated with their study of physics at high school. Examples of this were the acknowledgements by most of them that the course had taught them to take more responsibility for their own progress and that it had developed their initiative. Such personal development benefits were related in a positive sense with classroom teaching approaches which featured a well-integrated experimental component, a provision for student autonomy and attention to the social relevance of physics.

The proportion of students interested in studying physics at tertiary level was quite high in comparison with the State-wide enrolment figures for physics undergraduates. The average number of Third Year Physics undergraduates throughout the State at the time was 134, and yet 141 students in the research sample expressed interest in majoring in physics. Had the rate of interest of the sample applied State-wide in 1977 there would have been an estimated 1,836 students interested in a physics major. Interest in tertiary physics was positively related to classroom approaches which featured a low level of student frustration, and, yet again, a well-integrated experimental component together with attention to the social relevance of physics.

TABLE 2

Zero - order Correlations between Level of Student Frustration
and Other Student Outcomes Using Class Means (N=46)

CORRELATION	OUTCOME
-.67***	Developed Initiative
-.66***	Recommended Course
-.64***	Major in Physics
-.63***	Student Interest (Scale)
-.58***	Like Science
-.56***	Personal Development (Scale)
-.51***	Some Tertiary Physics
-.49***	Aggregate on Trial H.S.C. Physics Test
-.49***	Improved Study Methods
-.46***	Sense of Responsibility
-.42**	Physics not Isolated
-.37**	Mutual Assistance from Peers
-.34**	Satisfying Sense of Achievement
-.29*	Physics Relevant to Everyday Life
-.27*	Early Day Scientists Significant
-.16 N.S.	Appreciate Persistence at a Task

*p < 0.050, **p < 0.01, ***p < 0.001

N.S. denotes not significant at p < 0.050

It is well to be aware of the fact that the high schools participating in the research were not selected randomly across the State. Rather, the invitation to participate went only to non-government schools in which a particular Trial H.S.C. Physics Test was to be used. This test provided a common measure of physics achievement for the H.S.C. student sample.

Figures Two and Three summarize the main features of one of the key analyses undertaken in the study. Figure Two shows a significant canonical correlation (0.618) between the Classroom Environment factor and the Student Outcome factor. The other numbers in Figure Two are structure coefficients, which are the zero-order correlation coefficients for the original variables and the factors. These were found to be much more meaningful and useful than the standardized weights or betas used to generate the canonical factors, largely on account of the inter-correlations between several of the variables in the analysis (cf., Gordon, 1968).

Figure 2. Correlations Based on First Canonical Factors for Classroom Environment and Student Outcomes Using Class Means (N = 46).

ROLE OF EXPERIMENTS	.804	E N V F I A R C O T		O U F	.883	INTEREST
STUDENT AUTONOMY	.643	N O	.618	T A C C	.846	PERSONAL DEVELOPMENT
EMPHASIS ON EXPERIMENTS	.414	M R	(p = .013)	O T		
		E		M O	.566	TERTIARY PHYSICS
		N		E R	.170	PHYSICS ACHIEVEMENT
		T				

The variance overlaps shown in Figure Three were calculated by a method devised by the researcher. The proportion of variance extracted by each factor is first calculated by taking what is equivalent to the average of the squares of the structure coefficients for the particular factor. When this is multiplied by the square of the canonical correlation coefficient the result is what Stewart and Love called the redundancy of one set of variables given the other set (Stewart and Love, 1968). This is a measure of the variance overlap between the two sets of variables, as distinct from the overlap between the two factors. This notion was extended by simply distributing the redundancy across the contributing variables according to the ratios of the squares of the corresponding structure coefficients, thus giving the variance contributed to the multivariate relationship by each of the original variables. Structure coefficients were used in a similar fashion when interpreting multivariate regression analyses.

Figure 3. Variance Overlaps for Classroom Environment Set of Variables and Student Outcomes Set of Variables Using Class Mean Scores (N = 46).

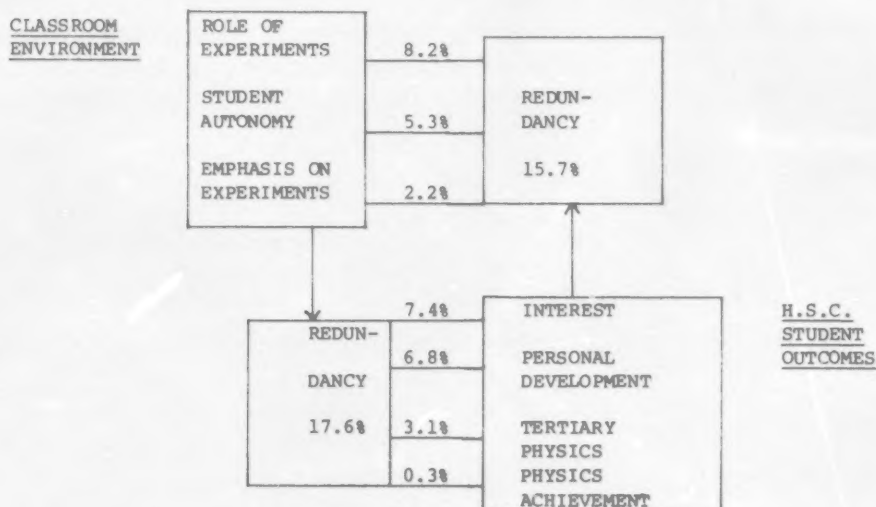


Figure Three shows that classes characterized by well-integrated experimental component and by student autonomy were likely to produce students with a strong interest in physics and an appreciation of the beneficial effects of the course on their personal development. The fact that the contribution of the Achievement measure to the relationships was negligible may appear to be disappointing at first, but it is as well to keep in mind that research has shown that "achievement measures have generally proved to be rather insensitive to differences in teaching methods" (Crawley and Shrum, 1977: p.257). The research which accompanied the initial production of Project Physics in the U.S.A. found no significant relationships between the physics course followed and physics achievement. The point made by Welch at the time applies to the findings of the present research:

"Perhaps the more important implication is that the attitudinal goals of the course were achieved without a resulting loss in physics achievement" (Welch, 1973: p.374).

Achievement was found to be significantly and positively related to other student outcomes and to teacher attitudes to teaching approaches encouraged by Project Physics.

The physics undergraduates surveyed showed, as could be expected a significantly higher level of interest in physics than did the high school students who were surveyed. Most of the undergraduates evaluated their high school physics course favourably, saying, for instance, that time spent on experiments and history was time well spent, and that the course prepared them well for tertiary level study of physics, especially in several areas of mechanics.

Physics achievement at university was not significantly related to the teaching/learning approach used during the earlier high school physics course. However, it was associated positively with academic achievement at high school especially in physics. The patterns of achievement on first semester physics were similar for the men and the women undergraduates.

CONCLUSIONS

Of all the aspects of classroom environment studied in this research, attention to the social relevance of physics had one of the strongest associations, in a positive sense, with each of the student outcomes.

The research showed that positive student outcomes tended to be closely associated with low levels of frustration.

Integration of experimental and theoretical aspects of physics tended to be accompanied by positive student outcomes. The integration could well go beyond using experiments merely to illustrate and/or verify principles and theories previously taught. At least in some topics, student understanding of physics could well follow upon and be the outcome of experiences gained during practical work, and some problem-solving by experiments could be given.

Despite some inevitable tensions, teachers who favoured student autonomy were generally satisfied with their physics teaching. Moreover, their students reported more growth in personal development areas such as a sense of responsibility than did students who did not experience much autonomy. The multi-media characteristic of Project Physics makes it a particularly suitable approach for including student autonomy.

The results indicated that academic achievement is not likely to suffer when attention is given to encouraging student initiative, sense of responsibility, improved study methods and persistence at a task. Such goals are long-term goals and working towards them tends to be accompanied by greater interest in and enjoyment of physics.

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INFLUENCE OF PRACTICAL WORK ON TEST PERFORMANCE

Elaine P. Atkinson and Richard T. White

The importance of practical work to the learning of science is widely accepted in Australia and many other countries. This acceptance seems to be based on intuition rather than evidence, since from the early studies reviewed by Cunningham (1946) through more recent reviews and studies such as those of Kruglak (1952), Bradley (1968), Yager, Engen, and Snider (1969), Pella and Sherman (1969), and Kilburn (1972), it has been hard to show consistently that practical work aids the learning of anything other than manipulative skills. This is an unsatisfactory state of affairs, since administrators seeking to cut costs might focus on laboratories, which could not be defended effectively on present evidence. Yet the intuitive valuation may be correct, so a serious error could occur. Recent developments in cognitive psychology provide both a theoretical rationale for laboratory experience and an explanation for the negative or conflicting results of past studies.

The developments involve changing one's view of teaching from a two-element, single-stage paradigm of instruction affecting performance to a three-element, double-stage one of instruction affecting memory which in turn affects performance. Until now, investigations have involved varying the instruction and looking for differences in performance. The new paradigm requires the investigator to vary the instruction, to look for differences in memory, and then to see whether these differences are related to differences in performance. This paradigm needs an appropriate model of memory and a means of probing learners' memories.

Gagné and White (1978) provide a model which is well-suited to the sciences. They propose that there is a long term memory store which contains four kinds of element: verbal knowledge, intellectual skills, images, and episodes. Verbal knowledge is facts or beliefs stored as propositions; intellectual skills are capacities to perform classes of tasks such as classifying objects or working through mathematical algorithms; images are mental pictures; and episodes are memories of events which the individual took part in or observed. Gagné and White postulate that recall of any element is enhanced by it being linked in memory to other elements, and that performance on tasks relating to a topic is more likely to be successful if the individual's memory contains a large number of interlinked elements concerning the topic. This provides a direct rationale for laboratories: practical work should lead to the formation of episodes, which should be linked to the facts and skills acquired in other lessons.

When earlier studies failed to find that practical work had a positive influence on performance, this may have been because the practical experience did not lead the students to store an episode or because they did not link it to the facts and skills which were tested. This brings us to the second consequence of the new paradigm, the need for a means of probing memories, because we will have to check whether episodes are present and whether they are linked to facts and skills. Despite misgivings some researchers (e.g. Hollenberg, 1970; Di Vesta, Ingersoll, & Sunshine, 1971) may have about self-report data, others (e.g. Bloom & Broder, 1950; De Groot, 1966) believe that the simplest and most valid method may well be to ask the learners about their own thoughts. That is the course adopted in the present study.

The purpose of this study is to see whether typical laboratory exercises do lead students to form episodes, and if so to see whether linking of the episodes to facts and skills is strong enough to affect performance. The research questions are:

1. Are students who perform laboratory exercises more likely to form episodes of the event than students who see the exercise demonstrated by their teacher?
2. Do students who perform laboratory exercises recall propositions better than students who see the exercise demonstrated by their teacher?
3. Do students who perform laboratory exercises recall intellectual skills better than students who see the exercise demonstrated by their teacher?
4. Are students who perform laboratory exercises better able to transfer intellectual skills than students who see the exercise demonstrated by their teacher?
5. Is accurate recall of facts generally accompanied by recall of experimental episodes?
6. Is accurate recall of skills generally accompanied by recall of experimental episodes?
7. Is transfer of skills enhanced by recall of experimental episodes?

METHOD

Sample.

The participants were 78 year 10 students in four classes in one suburban high school. There were two teachers, each with more than five years' experience, who had two classes each.

Subject matter and teaching materials.

The participants were to learn about the gas laws. A learning hierarchy of intellectual skills was written, with the pinnacle skill being to calculate the new volume of a quantity of gas at a new pressure and temperature. Propositions related to the skills in the hierarchy were specified. Two experiments with gas syringes were chosen, to illustrate Boyle's and Charles' Laws. The postulated pattern of logical associations between the skills, propositions, and experiments was thus determined.

A set of five programmed booklets was written, for use in teaching this subject matter over five school periods. the Boyle's Law experiment was incorporated in the third booklet and the Charles' Law in the fourth.

A retention test of 18 items was prepared. It contained 8 items which tested recall of intellectual skills in a form close to that in which they had been taught, 6 which listed recall of facts, and 4 which tested transfer of intellectual skills to new contexts. For all but two items the scoring was to be 1 for completely correct, 1/2 for partly correct, and 0 for incorrect. Items 8 and 18 were more complex than the others, as one tested the retention and the other the transfer of the pinnacle skills, and so they were scored 2 for completely correct and from 1/2 to 1 1/2 for a range of partially correct answers.

Procedure.

One class for each teacher was assigned randomly to do the experiments in small groups, of two or three, while the other class was to have the experiments performed for them by the teacher while they recorded the measurement. The students in both groups worked through the programmed booklets, and either did the experiments or had them demonstrated to them at the planned times.

Following the instruction, after two days and again at six weeks, the students one at a time were given the retention test. As the students finished each question, they were asked "What thoughts or pictures flashed through you mind while you were deciding how to answer the question?", and then "Any other thoughts or pictures which flashed through you mind?" The students' responses were taped recorded.

Immediately following the retention test, on both occasions, each student was shown a photograph of the apparatus used in the Boyle's Law experiment and asked "Here is a picture of some apparatus used in an experiment. Can you tell me if you can remember this experiment and, if so, what you can remember about it." This was repeated for the Charles' Law experiment. The responses were recorded.

RESULTS

Question 1. Formation of episodes of the practical work or the demonstration was shown by recognizing the photograph of the apparatus. The students' responses are shown in Table 1.

TABLE 1
Numbers of Students Recognizing Apparatus
Retention Period

Recognized Apparatus	2 Days		6 Weeks	
	Practical	Treatment Group Demonstration	Practical	Demonstration
Boyle's Law				
Yes	38	40	37	39
No	0	0	1	1
Charles' Law				
Yes	37	30	36	27
No	1	10	2	13

The results in Table 1 show that practically all students had episodes of Boyle's Law practical work or demonstration both at two days and six weeks after the end of instruction, so for that experiment there is no difference between the two treatment groups. For the Charles' Law experiment, however, the demonstration group shows a considerable decline in recognition. Their performance after two days is so low, and the further decline over six weeks so relatively slight, that it seems that many in this group did not process the demonstration at all, so that they may never have formed an episode in the first place. It is remarkable that only a few days after seeing the demonstration a quarter of the students could not recall ever seeing the apparatus. All but one student in the other groups, who did the experiment in small groups, recognized the apparatus. Question 1 is answered affirmatively for Charles' Law.

Questions 2 to 4. Mean scores for the two treatment groups on the three scales of the retention test are given in Table 2.

TABLE 2 - Mean Scores on 3 Scales of Retention Test at 2 Days and 6 Weeks

Scale	Treatment Group	
	Practical	Demonstration
	2 Days	
Proposition retention	3.62	2.96
Skill retention	6.54	5.26
Skill transfer	2.43	2.10
	6 Weeks	
	3.54	3.19
	5.57	4.48
	1.88	1.64

Note: n=38 for practical group and n=40 for demonstration group.

The scores were subjected to two-way analysis of variance with one repeated measure. The interaction between treatment group and time of test was not significant for any of the three scales, and a significant main effect for treatment group was found only for the skill retention scale, for which the practical group was superior. This group did better on the other two scales also, but not sufficiently so to reach statistical significance. Thus only question 3 of the three in this section can be answered affirmatively, and the others, as has been the case in many previous studies, are left in doubt.

Questions 5 to 7. Table 3 gives the numbers of students who referred to the science experiments and other episodes when asked after each question what thoughts or pictures came into their minds while answering the question. Clearly they rarely referred to the experiments except for item 7, which stated "A certain volume of the gas oxygen is contained in a gas syringe. What is the effect on the volume of increasing the gas temperature, the pressure remaining constant?" The strong cue provided by "gas syringe" may be responsible for the exceptional result with this item.

Since there are so few references to episodes of the experiments it is pointless to try to answer questions 5 to 7. However, the lack of references is of some significance, and this result is taken up in the discussion.

TABLE 3

Numbers of References to Episodes When Answering Items

Item	Episodes about			
	Experiments		Other Events	
	Retention Time			
	2 Days	6 Weeks	2 Days	6 Weeks
1	0	2	29	26
2	1	0	50	44
3	3	4	9	13
4	0	0	28	37
5	0	1	50	49
6	0	0	33	25
7	35	24	18	14
8	1	0	42	39
9	1	1	24	27
10	0	0	25	20
11	0	0	35	34
12	1	0	28	26
13	1	0	33	27
14	0	0	25	22
15	0	0	10	8
16	1	0	20	23
17	0	0	25	22
18	0	0	23	16

DISCUSSION

The results indicate that practical work leads to formation of episodes while for demonstrations this is less certain; there is some advantage to the recall of intellectual skills in doing laboratory work; once episodes are formed they are stable; and links between skills or facts and practical or demonstration episodes are rarely reported. This last result may be because there are no links to report. However, the observation that nearly half of each group reported thinking of episodes relating to the experiment when doing item 7 suggests that the links are there but are generally not called on.

Three explanations for why the students did not call on the episodes when answering items are that they did not need them, they did not see the episode as relevant, or they did not have strong links between the items and the episodes. These explanations are not mutually exclusive, and there is evidence in support of each one.

Detailed study of the students' oral responses shows that on many occasions they reported that they simply remembered how to do the item without any other conscious thoughts. The information was so readily available that there was no need to search around in memory, and so no need to activate linked episodes. There is an interesting contrast between two groups of students who both performed well at the first retention test. One group reported simply remembering many of the items, while the other groups had to search their memories and invoked images and episodes (generally of events other than the experiments). At the second retention test six weeks later, the first group continued to do well but the performance of the second group fell away. This suggests that links are used only when the required information is not readily available, such as when it has not been overlearned or when a complex problem is being attempted. This could be checked by including in the retention test items that are not as closely related to the subject matter that has been taught.

Evidence that the students did not find the experiments relevant to the test items is shown by the result that although they rarely thought of the experiments, except in item 7, they did think of many other events. Frequently these were events that occurred while they were working through the booklets, but they did include events that happened up to ten years earlier.

The lack of strength of links to the experiments is shown by the different response to item 7. The link between an item and the experiment was activated only when the experiment was cued strongly, as it was in item 7. If these links had been strong, one would have expected the experiments to have been thought of much more often, and more evenly across the items as their activation would be less dependent on cueing. A definite attempt was made in the booklets to emphasize the relation of the experiments to the propositions and skills. The relative failure of this attempt may be paralleled often in classrooms with teacher-controlled instruction. That should be investigated.

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STUDENT PERCEPTIONS OF THE INFLUENCES OF
PRACTICAL WORK IN SCIENCE AT HIGH SCHOOL AND MATRICULATION LEVELS
IN TASMANIAN SCHOOLS

P.P. Lynch and V.L. Ndyetabura

INTRODUCTION

It is widely accepted that practical work in school science is valuable in developing an understanding of the principles and concepts of the subject areas as well as establishing positive attitudes towards and interest in science (Kerr, 1963). Some science educators believe that the major role of practical work should be to provide students with the opportunity to engage in processes of investigation and inquiry (Lunetta and Tamir, 1979), though most writers are less confident about the extent to which taxonomically defined outcomes are achieved in practice.

The purpose of this paper is to examine student perceptions of the outcomes of practical work, termed 'influences', by us. A list of possible influences was obtained by considering the stated aims of practical work derived from modern curriculum programmes and educational writings. Minor syntactical changes convert the aim (according to educators) into an influence (as perceived by students).

For comparative purposes the list of possible influences was based on the aim/influence list used by Kerr (1963), West (1970), Thompson (1975) in the U.K. and Lynch (1976) in South Africa. Our final list of ten influences (Table 1) is rather more extensive than the six used by Kerr and West, but less itemised than that used by Thompson.

We have chosen not to make overt distinctions between 'content' and 'process', at least at this stage. Neither have we used a Bloom-type taxonomical classification, though the items can be grouped into those familiar categories.

In this study, practical work means experiments performed by the teacher as demonstrations, co-operative demonstrations by groups, as well as experiments and observational exercises carried out by students. The activities may take place in the laboratory or elsewhere (i.e. field work).

The study took into account variables such as sex differences, size and type of school, and final academic performance in science of students. Thus it was possible for us to investigate the relationship, if any, between perceptions of practical work and important background and performance variables.

The study was also designed, in part, to gauge to what extent recent curriculum innovations and changing ethos in Tasmanian schools has affected the students' perception of practical work in what could be considered a post-curriculum phase.

TABLE 1
Possible Influences of Practical Work as Perceived by Students

- 1 Helped me to make observations more carefully.
- 2 Helped me to interpret observations in a logical way (e.g. to ask questions and not to make decisions unless there is suitable evidence for doing so).
- 3 Made the theoretical parts of science clearer to me.
- 4 Made the theoretical parts of science more real and interesting to me.
- 5 Led me to find out facts and principles for myself (i.e. new ideas and information were acquired through experiments first rather than from explanations from the text books and teachers).
- 6 Gave me training in the skills and techniques of laboratory work.
- 7 Has taught me how to conduct laboratory experiments in an organised way.
- 8 Has prepared me directly for final examinations (i.e. my overall mark will probably be higher because of the practical work I have seen or done at school).
- 9 Gave me a personal interest in practical work and experimentation.
- 10 Has encouraged me to study science or related subjects further after leaving school.

METHODS

Design of the Test-Instrument

The list of ten possible influences was constructed after a careful literature survey of similar studies. Questionnaire items were validated locally by an advisory steering committee composed of 17 persons actively involved in Matriculation and High school teaching and assessment.

The Student Samples

The sample of High school students (N = 459) was obtained from a stratified cluster of all Tasmanian schools. In all, twenty-one High schools were selected from a sampling frame stratified as rural/urban and state/catholic/independent, thus ensuring that the student sample reflected the various types of school in the total population. Individual schools provided a sample of approximately 25 pupils (about one 'class worth') at Grade 9 (Age 14-15) that would be representative of the grade/age level. In schools where there was no streaming, a single class group was used. In other cases a sample of the streamed groups (termed level III, II and I in the Tasmanian system) was selected randomly from the total complement of Grade 9 students at that particular school.

All Matriculation level students in Tasmania (N = 265), response rate 90%, attempting the Physics or Chemistry 'B' courses at Grade 12 (Age 17+) completed the Influence test. Almost all this group had completed the Physics and Chemistry 'A' courses in Grade 11, usually successfully, and were beginning the more specialized 'B' courses which are usually only undertaken by those oriented towards University or other tertiary studies in science and engineering.

It should be appreciated that the two samples (one a total population) describe two rather different groups. The High school students sample represents the average 14-15 year old at Grade 9. The Matriculation level population represents those academically successful students oriented towards tertiary study in science or science-related fields.

PROCEDURE AND ANALYSIS OF DATA

In this study, students were required to read the list of ten influences, carefully, for 5-10 minutes and think about them. They were then required to 'choose what you think were the four most important influences from the list below'. High school students referred to their experience of previous High school work while Matriculation level students were instructed to consider their previous Matriculation level course in Grade 11.

Thus each student had to choose 4 items from the 10. If an item is chosen it scored 1, if not chosen it scored 0. The total scores recorded for each item could then be expressed as a frequency and the items rank ordered if necessary. We have placed more emphasis on frequencies than rank order, and where differences between groups are considered, the statistical significance has been ascertained using z-tests to establish the 0.01 significance level.

RESULTS

For clarity and comparative purposes the data for both High school and Matriculation college students is presented conjointly, initially for 'all' students and subsequently for the effect of the variables: sex difference, academic performance, and type of school. The frequency of students' responses for each influence is given in Table 2. In the case of High school students, four influences ('careful observation'; 'made theory more real and interesting'; 'prepared me for final examinations'; 'has encouraged me to study science further') are significantly different from a random response frequency of 40%. The first two influences named are greater than, and the last two influences are scored less than a random response frequency. In other words influences 1 and 3 were considered to be relatively important while influences 8 and 10 were considered to be relatively unimportant by High school students.

In the case of Matriculation level students, six influences ('made theory clearer'; 'made theory more real and interesting'; 'training in skills and techniques'; 'finding out for myself'; 'prepared me for final examinations'; 'has encouraged me to study science further') are significantly different from a random response frequency. The first three influences named were considered to be relatively important and the last three influences relatively unimportant by this student group.

A comparison between the two student groups indicates that major changes occur in students' perceptions of the importance of four influences ('careful observation'; 'made theory more real and interesting'; 'finding out for myself'; 'training in skills and techniques'). Both student groups are in agreement about the relative importance of influence 3 and about the relative unimportance of influences 8 and 10. Matriculation level students are considerably more discriminating than High school students in their perception of the relative importance of the influences.

The Association of Sex Difference with Perception of Influences

At High school level there is only one influence which is associated with a difference that is significant at $p < 0.01$, that is 'finding out for myself'. Girls are more positive than boys about this particular influence. There are smaller differences associated with influences 1, 3 and 7 but strictly they are not within the criterion of 1% statistical significance.

TABLE 2

Students' perceptions of the relative importance of the influences of practical work at high school and matriculation level

Possible Influences	High School Students (% response)	Matriculation Level Students (% response)
1. Careful observation	a 1(57)†	a 7(35)
2. Interpret observations logically	3(44)	4(46)
3. Made theory clearer	2(50)†	2(59)†
4. Made theory more real and interesting	6(41)	3(57)†
5. Find out for myself	3(46)	8(32)†
6. Training in skills and techniques	8(38)	1(64)†
7. Experiment in an organised way	4(45)	5(40)
8. Prepared me for final examinations	9(17)†	10(11)†
9. Personal interest in practical work	7(40)	6(39)
10. Has encouraged me to study science further	10(9)†	9(12)†
N	459	265

a = rank order of influence

† = items for which the response frequency is significantly different to a random response (4 items from 10) of 40%; at $p < 0.01$.

Girls at Matriculation level are more positive about influences 2 and 6 ('made theory clearer'; 'training in skills and techniques') and more negative about influence 7 ('experiment in an organised way'). The responses for influences 3 and 6, 68% and 75% respectively, are amongst the highest recorded for any influence for any student sub-group studied so far.

Generally, sex difference is not associated with perception of influence of practical work.

TABLE 3

The association of students' perceptions of influence of practical work with sex difference

Possible Influences	High School Students (% response)		Matriculation Level Students (% response)	
	Boys	Girls	Boys	Girls
1. Careful observation	53	60	37	31
2. Interpret observations logically	43	46	46	45
3. Made theory clearer	46	53	56	68 *
4. Made theory more real and interesting	42	41	56	61
5. Finding out for myself	41	51 *	33	29
6. Training in skills and techniques	40	35	60	75 *
7. Experiment in an organised way	49	42	44	29
8. Prepared me for final examinations	17	6	12	11
9. Personal interest in practical work	44	38	39	39
10. Has encouraged me to study science further	9	8	12	11
N	228	229	190	75

* = differences between groups are statistically significant at $p < 0.01$

The Association of Academic Performance with Perception of Influence

Students were divided into three groups (low, medium and higher performers) based on their end of year marks in physical science in the case of the High School students, and on their achieved Matriculation grades in Physics and/or Chemistry in the case of Matriculation students. (See Table 4 for details).

At High school, although there are some interesting differences notably associated with influences 3, 4, 5 and 7, only influence 7, 'experiment in an organised way' is significantly different at $p < 0.01$. It should be noted that these differences are due to the responses of the low performers.

At Matriculation level, there are four influences, ('made theory clearer'; 'experiment in an organised way'; 'prepared me for final examination'; and 'personal interest in practical work') where differences between responses are statistically significant at $p < 0.01$. Again, where differences exist they are due specifically to the responses of the low academic performers.

Academic performance is not associated with perception of influences for the medium and high performers but low performers respond differently at matriculation level.

The Association of School Type with Perception of Influences

The three major divisions of school type in this survey are state schools, catholic schools and independent schools. At High school level, six influences are significantly different (influences 3, 4, 5, 6, 7 and 9), while at Matriculation level three influences are significantly different (influences 5, 7 and 10). School type is associated with perception of influence of practical work to a considerable extent, particularly at High school.

DISCUSSION

Student perceptions of the relative importance of the influences of practical work at both the end of High school and at Matriculation level show evidence of ordering. This ordering is clear at Matriculation level though the range of responses for individual influences is only slightly greater than that observed for High school students (64%-11% cf 57%-9%). An absence of ordering would occur if each influence received a response percentage of 40%. Such a situation could be due to either a random non-purposive selection of influences or to a very substantial variation between individual respondents.

What emerges from the overall responses at High school level is that 'careful observation' and 'made theory clearer' are relatively important influences according to students and 'has encouraged me to study science further' and 'prepared me for final examinations' are relatively unimportant influences. The remaining six influences are closely grouped and could be interpreted as tied in terms of rank order.

At Matriculation level the separation between the responses is much more well-defined and it is observed that three influences ('made theory clearer'; 'made theory more real and interesting'; 'training in skills and techniques') are relatively important according to students at this level while three influences ('finding out for myself'; 'prepared me for final examination'; and 'has encouraged me to study science further') are considered to be relatively unimportant.

TABLE 4

The association of students' perceptions of influence of practical work with academic performance in science^a

Possible Influences	High School Students (% response)			Matriculation Level Students (% response)		
	Academic Group ^a Low	Med	High	Academic Group ^a Low	Med	High
1. Careful observation	61	58	52	43	33	40
2. Interpret observations logically	41	42	48	50	45	47
3. Made theory clearer	39	52	51	36	56	68
4. Made theory more real and interesting	31	43	43	57	62	56
5. Finding out for myself	44	41	52	21	32	18
6. Training in skills and techniques	39	37	38	64	62	69
7. Experiment in an organised way	54	49	40	64	34	43
8. Prepared me for final examinations	15	16	17	0	12	12
9. Personal interest in practical work	42	45	37	57	39	35
10. Has encouraged me to study science further	7	6	11	7	14	13
N	59	173	214	68	89	14

^a At High school level, awards are Credit, Higher Pass, Pass, Lower Pass, Fail.

For our purposes HIGH = C or HP; MEDIUM = P; LOW = LP or F.

At Matriculation level, awards are Credit, Pass, Lower Pass, Fail, in Physics and Chemistry.

For our purposes HIGH = C+P or greater; MEDIUM = P+P, LOW = LP/F.

A comparison between the two student groups shows that the greatest changes in perceived influence are associated with 'careful observation', 'made theory more real and interesting', 'finding out for myself' and 'training in skills and techniques'. The direction of these changes are of considerable interest in that the Matriculation students perceive their practical work to be much more technique oriented and much less associated with careful observation than the High school students. Matriculation level students also place 'finding out for myself' in 8th place with a response rate of 32% - considerably lower than that recorded for High school students.

These responses from High school students are of interest in regard to the science curricula operating at present in Tasmanian schools which have been affected by ASEP, and to a lesser extent by Nuffield, ISCS and JSSP. A considerable amount of student-directed practical work takes place but from the writers' experience it is very simple, instant and visual with a minimum of genuine experimentation. Not surprisingly the High school student's perception is perhaps more of a visual aid than an experimental enterprise.

By comparison, Matriculation syllabuses in physics and chemistry in Tasmanian schools tend to be very 'tram-lined'. Matriculation chemistry is a modified form of chem. study which is divided into two distinct parts, each of one year duration. A similar approach is adopted for matriculation physics though the effects of established curricula are less well-defined. Although the intention of both syllabuses is to encourage discovery learning, students' perceptions at present constitute a highly technique-oriented practical component at Matriculation level. 'Training in skills and techniques' emerges as the most important influence with a response rate of 64%, while 'finding out' is ranked 8th with a response of 32%. It is interesting to note that the same group of students rank 'careful observation' 7th with a response of 35%. The 'training in skills and techniques' emphasis is particularly strong as far as chemistry students are concerned. A small number of students (N = 16) were involved with Matriculation chemistry only (i.e. not both physics and chemistry) and the response percentage for this influence was 74% for this group - 18% higher than the next most important influence. This represents quite a disturbing emphasis since it would appear that the practical components of both physics and chemistry and particularly for the latter subject have metamorphosed into quite the opposite of what was intended.

One should add that the teachers involved are mainly honours graduates and subject specialists whose professional competence is not questioned.

There are one or two differences in the perceptions of boys and girls mainly at the Matriculation level where all teaching and instruction in science is co-educational. However where differences exist they are a matter of degree and the rank order of influences for boys and girls is virtually identical. Consequently, we suggest that student perceptions of practical work is not associated to any extent with sex difference of students.

Overall academic performance is not associated with perception of the influence of practical work for medium and high performers but there are some interesting differences in the responses of the low performers - i.e. the unsuccessful academic group. These differences are most noticeable at Matriculation level. Low academic performers are particularly conscious of 'training in skills and techniques' and 'experiment in an organised way' while 'made theory clearer' is perceived to be much less important as an influence. It may be that the practical work employed is unsuitable for the lower ability groups in that it involves them in psycho motor/organisational activity with little cognitive reinforcement. Certainly, this group and their responses

need to be looked at most carefully by science teachers and educators particularly if Matriculation studies in physics and chemistry are considered to be part of a general education and not simply as a filter for tertiary studies.

Students' perceptions of the influence of practical work appear to be associated with type of school, particularly at High school level and this suggests that practical work in schools can be and is perceived substantially differently within school groupings. This is not a trivial point, and comments on the doubts that teachers and educators might have on whether curricula and/or individual teachers effect major differences in orientations towards an enterprise such as practical work. Pursuing this point we have made a careful study of the responses of individual schools and related them to curriculum descriptions. Although it is inappropriate to report the detailed findings at this point, it should be noted that they fully support the observations made in this paragraph concerning association with type of school.

In conclusion we would argue that goal-oriented studies of the type described in this paper would seem to be of a considerable value in illuminating the teaching process, in spite of the somewhat a-theoretical frameworks adopted.

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THE USE OF PROBLEM-SOLVING IN MEANINGFUL LEARNING IN BIOLOGY

Margaret Brumby

Many teachers have had the rather humbling experience of reading students' answers to a question, only to find that a number of students have apparently not understood the concept on which the question is based. These students are not necessarily ignorant about the particular concept (i.e. no knowledge), but their explanations show they are wrong about it. Despite correct teaching, and reading correct textbooks, students somehow have learned incorrectly. Why does this occur?

Marton (1975) defined active learning as 'something which you do', in contrast to passive learning, which is 'something which happens to you'. This extends Ausubel's (1968) distinction between meaningful and rote-learning, for it emphasizes how rather than what you learn. Ausubel recommended the use of novel, or unfamiliar problem-solving as a method with which to evaluate meaningful learning of concepts.

In the 1976 Victorian HSC Biology examination, the compulsory essay was a problem based on the concept of natural selection. As co-ordinator of marking, I became aware that many hundreds of students had written essays which described a Lamarckian view of evolution. This paper describes research designed to explore the development of meaningful learning in biology, and the origin of misunderstandings, using the concept of natural selection.

DATA-COLLECTION

Five problems requiring application of the concept of natural selection were developed. Three were presented as A. part of a written set, and two as B., part of an individual interview.

A Written set

A.1 The insecticide problem

'When they were first sold, aerosol insecticides were highly effective in killing flies and mosquitoes. Today, some 20 years later, a much smaller proportion of these insects die when sprayed. Why do you think this is so?'

A.2 The dinosaur problem

'About two hundred million years ago, dinosaurs roamed the earth. They were huge creatures, some reaching lengths of over 100 feet. Most dinosaurs lived in water part of the time and on land part of the time. Most dinosaurs were plant eaters and they ate large amounts of plants of all types and sizes. The plants they lived on were found in and around water.

Write a short paragraph which explains why you think dinosaurs are no longer found.'

A.3 The antibiotics problem

'Scientists have warned doctors against the increasing use of antibiotics (e.g., Penicillin) for treating minor infections. What is the reason for their concern?'

B Interview

B.1 The skin problem

'If we suppose that man originally arose in one place, say in Africa, where some of the oldest human skulls have been found, then how do you account for the different skin colors that exist in the different races around the world today?'

After students had given their explanation I asked two further questions:

- (a) 'What would you predict to happen to this couple's skin (dark-skinned), if they went and lived permanently in Norway?'
'If they had children born in Norway, what would their children's skin look like at birth?'
- (b) 'What would you predict to happen to the skin of this little girl, (very light-skinned) if she went and lived in Africa for the rest of her life?'
'If she married someone of her own race, they lived in Africa, and had children there, what would their children look like at birth?'

B.2 Concepts identification question

'What are the basic concepts or ideas that are contained in these questions?'

All these problems and questions explored the understanding of the concept of natural selection.

In the insecticide problem both the change in the environment, (the introduction of insecticide), and the target population (insects) are identified.

The problem of extinction (the Dinosaur Problem) is an example of 'negative' selection, i.e., why a species does not survive. The essential (missing) step to be identified by students is that there must have been a change in the dinosaur's environment. Analysis of this problem with a group of American students has been described elsewhere (Renner, Brumbu and Shepherd, 1981).

In the antibiotic problem the change in the environment (addition of antibiotic), is again identified, but now there are two populations present - bacterial and human, and students have to identify the target population.

In the skin problem, students needed to explain that there must be a selective advantage in having a lighter skin in colder climates, and also that the presence of pigment gives a selective advantage in tropical countries. Before asking the final 'concepts identification' question I put the student's own written answers to the insecticide and antibiotics problems before them.

Student Population

The entire 1978 first-year intake (52 students) of two courses of the Department of Human Biology and Health at a British University participated in this study. Forty-five students (87%) had come to university immediately following their A-level exams. All except one student had studied a biological science subject at A-level.

ANALYSIS OF RESULTS

Categories used in analysis were developed by reading students' answers and finding common points, i.e., they were not pre-determined categories. The results of the four problems are discussed below. These separate results were then combined to determine, for each student, their overall understanding of the concept of evolution by natural selection. The fifth question, the concepts identification question, was analysed separately.

A.1 Twenty five percent of all students correctly explained the insecticide problem in terms of selection. The rest either did not understand the problem or were unable to express themselves accurately.

'The insects have gradually, over the years, obtained immunity to the insecticides. These immunity factors passed on from generation to generation, gradually building up so immunity increases.

A.2 In the dinosaur question, only 19% correctly completely explained both key points, that following an (unknown) change in the environment, no dinosaurs had any characteristics enabling their survival, so all were selected against by the environment and died out. A further 42% identified the missing step, 'the climate changed', but either did not explain the consequences or went on to explain, 'the dinosaurs couldn't adapt and so they died.' Two students (4%) mentioned the phrase 'survival of the fittest', without mentioning any prior environmental change. The most common other reason was 'competition with other animals', 'insufficient food', 'restricted movements on land', and the familiar 'they couldn't adapt' accounted for the remaining 35% of students.

A.3 Although 29 students (56%) identified bacteria as the target population, only 3 students correctly explained the selective action of the antibiotics. The other 26 students all believed: 'bacteria become immune'. The remaining students (44%) incorrectly identified man as the target population:

'The body will become used to the antibiotics, .. may not react so strongly when treated, .. effectiveness will decrease.'
'The patient will develop an immunity to penicillin, and it may not work efficiently in a major illness.'
'If used in minor illnesses it will be of no use in serious illnesses, it will be useless and not work.'

B.1 Only 8 students (15%) correctly explained the hypothesis in terms of natural selection, the presence of pigment being advantageous or disadvantageous in the tropical or cooler climate respectively. There were three common errors in answering this problem:

- (i) the development of pigment is caused by U/V rays,
- (ii) loss of pigment is because it was not needed,
- (iii) by adaptation:
'Its adaptation to the power of the sun. There is a need for a filter in the skin to stop U/V rays penetrating. This need either increases or decreases, depending on the environment.'

The further questions on Norway and Africa migration and subsequent birth of children were designed to focus on the differences between changes occurring in one generation and changes occurring over many generations.

Migration of dark-skinned people to Norway troubled only two students, who thought the children might be born slightly lighter-skinned. The reverse migration, i.e., light-skinned people going to Africa and subsequently having children born in Africa proved more difficult. All students said that they would become suntanned or slightly darker, (but not black as Africans). Nine students (17%) predicted that their children would be slightly darker than they were - AT BIRTH i.e., in one generation.

Overall level of understanding of this concept: Using an ordinal scale of measurement, allocating 1 mark to each sound explanation in each problem, and 1/2 mark in Q.A.3. to the identification of the target bacterial population, and in A.2 to the change in the dinosaur's environment, students were grouped into Good (4 or more), Moderate (2-3) and Poor (1).

Only 8 students (15%) demonstrated good understanding of natural selection, Nine (17%) students showed moderate understanding. Over two-thirds of these 52 students (68%) were unable to recognize that these were problems of evolution by natural selection.

B.2 Concepts identification question: Students' answers to this oral question were analysed in two ways. The frequency of concepts was determined as shown in Table 1(a). They were then re-grouped according to the classification of students into levels of understanding. This distribution of concepts is shown in Table 1(b).

TABLE 1 - Concepts identified during task interviews

(a) Frequency of Concepts	TOTAL	%
Selection/evolution	13	25
Gene mutations	5	9
Resistance	9	17
Adaptation	4	8
Immunity	17	33
Chemicals/Drugs	4	8
TOTAL	52	100

(b) Distribution of concepts	Levels of Understanding			
	GOOD	MODERATE	POOR	TOTAL
Selection/evolution	7	4	2	13
Mutations/resistance	1	2	11	14
Immunity	-	1	16	17
Adaptation	-	1	3	4
Chemicals/drugs	-	1	3	4
TOTAL	8	9	35	52

Table 1(a) shows that 6 concepts were identified. Most students gave only one. Where more than one was given, the first one was used in distributing students. Nearly all these multiple answers were gene mutations and resistance. By combining these two, as in Table 1(b), these multi-answers were deleted.

Table 1(b) clearly shows the significance of the positive identification of natural selection/evolution concept, and confirmed the validity of the student's understanding of this concept, as determined by the set of four problems. This table also shows that those students who listed 'adaptation', and 'mutations', (which theoretically could be relevant concepts) were not using these concepts correctly. The misunderstanding of the concept of immunity was almost totally restricted to the group with very poor understanding.

Relationship between Meaningful Learning and Cognitive Styles

The cognitive styles of these students have been analysed using methods that were independent of their performance on the tasks reported here (Brumby 1981). Two sets of criteria were used in describing differences in cognitive style:

analytic and holist perception of a problem. Many workers have reported a consistent difference between students who break a task into its component parts (analytic) and those who see the whole of the task (holist). These are not mutually exclusive categories and students who show both characteristics have been termed versatile. Using a variety of tasks these students were found to be consistent in their category of perception, i.e., it was a characteristic of the student rather than the task.

(ii) a high or low ability to integrate new material with their existing knowledge. This criterion in cognitive style emerged as being distinct from (i) above, when students actively went beyond the information given in a task, in order to explain it to their own satisfaction. Categorization on this criterion was found to be more influenced by the content of a particular task or problem, than in (i) above.

How were the eight students who had shown sound understanding of the concept of natural selection, classed on these two sets of criteria? Four of these eight students were classed as versatile students (i.e., able to use both styles), and with a high level of integration. Two students were classed as versatile with a low level of integration, one student was classed as analytic with a low level, and the eighth student was classed as holist in cognitive style with a low level of integration.

DISCUSSION

Students with a sound grasp of the process of natural selection consistently explained these problems in the series of steps described in the pilot study (Brumby, 1979).

Analysis of the majority of answers revealed a consistent pattern of misunderstanding. In attempting to explain these problems, students with only a poor understanding of natural selection start with a change in the environment, which causes mutations, which by a process of adaptation, results in immunity to the effects of the change, hence survival, hence evolution. There are four significant errors, or gaps, shown by this reasoning:

- (i) the origin of the concept of diversity arising by spontaneous mutation is absent,
- (ii) adaptation has been moved down from a 'result' to a 'process' level, replacing selection,
- (iii) emphasis is on within one lifetime of an individual, with a frequent suggestion of anthropomorphism,
- (iv) the concept of immunity is linked closely into the evolutionary map.

According to Ausubel's definition of meaningful learning (1968), a student is able to recognize new and unfamiliar instances of a concept. The findings in this study indicate that the majority of (successful) A-level Biology students have not achieved this level of learning for the concept of natural selection.

The finding that 75% of students with sound understanding of this concept had also shown both analytic and holistic cognitive styles in an independent study, supports Pask's (1976) belief in the importance of versatility of cognitive styles or strategies (i.e., able to see both 'the forest' and 'the trees' of a concept).

The pattern of misunderstanding suggested a Lamarckian type of reasoning, i.e. of change on the basis of need. It is true that most secondary school Biology texts include both Lamarck's and Darwin's theories about the evolution of species. But why should Lamarck's idea of an adaptive process be retained by the majority of students, rather than Darwin's idea of a selective process? Even more importantly, why is there only a single pattern of misunderstanding; why not many different misunderstandings? I believe this 'intuitive' Lamarckianism illustrates a component of learning of fundamental importance, namely, the crucial role of personal experience in the development of meaningful learning.

'Change' is quite familiar within the lifetime of these students. Some changes are correctly called adaptations. A biological example is the adaptation of eyes to different light intensities, e.g., on entering a dark room from outdoors. In a sociological context much human behaviour is 'adapted' to the norms of society. A person 'adapts' to the effects of alcohol after many years' consumption. In all of these examples, it is commonly said that an individual has 'adapted' a specific characteristic to suit environmental needs. The phrase 'to adapt to change' has become a more popular expression than the direct verb 'to change'. This looseness in the use of the precise language of science, particularly concerning the term 'adaptation' has been strongly criticized by Lucas (1974). Osborne (1980) recently clarified the importance of recognizing that children's use of scientific words and scientists' language are not necessarily the same.

It is important to stress that all of the above examples of change, ('adaptations'), occur within a single lifetime of an individual. For most people, the time-span of meaningful thought involves their daily lives - certainly less than their own lifetime. There are few familiar experiences of a selective process.

Perhaps this is one of the factors contributing to this common pattern of misunderstanding. People extrapolate from their own first-hand experiences of response to a change in the environment, to account for the whole of evolution as a sequential process of adaptation to changes in the environment on a greater scale. As changes which occur within a lifetime are not genetically transmitted to future generations, when they do this they are ignoring two essential concepts related to the evolutionary process:

- (i) the time-scale, involving many generations. Explanations of observations to individuals within one generation are extrapolated to account for changes seen in populations across many generations.
- (ii) laws of inheritance. Students show only partial understanding of inheritance, believing that 'all characteristics are inherited' (genetic).

Nussbaum and Novak (1976) postulated that on the basis of common-sense world experiences students often develop misunderstandings of the physical world which are strongly held, and which interfere with the learning of new conceptual relationships. The findings described in this paper confirm and extend this in a biological context. As Gunstone and White (1981) said of tertiary physics students attempting concrete physics problems, 'students "know" a lot of physics but do not relate it to the everyday world'. Champagne (personal communication) has found that students' 'intuitive' ideas of physics concepts are Aristotelian rather than Newtonian, even at tertiary level. Deadman and Kelly (1978) described the existence of 'intuitive' Larmackian ideas of evolution in fourteen-year-olds. The 'intuitive' understanding of the majority of tertiary biology students, described in this paper, has not been corrected by their formal studies of Darwinian evolution. These findings support Ausubel's focus (1968) on the importance of prior relevant concepts in learning and problem-solving.

If I had to reduce all of education psychology to just one principle I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.

Implicit in the word 'accordingly' is the idea of integrating new concepts into a student's existing cognitive structure. This active process, which Ausubel calls meaningful learning, may be facilitated by using unfamiliar problems which are based in the real world.

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A CASE STUDY ANALYSIS OF DIFFERENCES IN LEARNING PROCESSES AND OUTCOMES IN BIOLOGY

John R. Baird and Richard T. White

This is a study of the processes by which individuals learn and understand new information. The aims were to analyse the dynamics of learning, and to evaluate the subsequent learning outcomes, for three adults as they progressed through a learning programme in genetics.

The learning paradigm on which this study is based is shown in Figure 1.

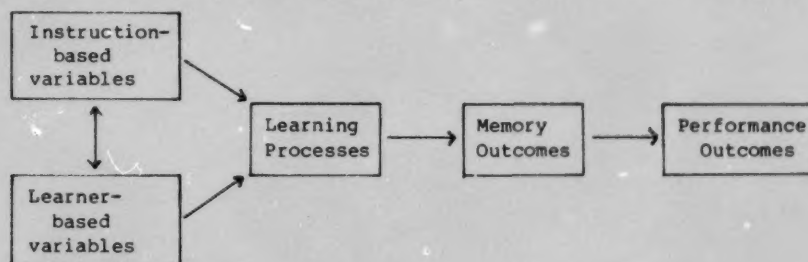


FIGURE 1. Model of Learning

Instruction-based variables are divided between cognitive and affective; the former being further broken down into instructional method, nature and organization of material, while the latter includes level of stress generation and nature and extent of reinforcement.

Learner-based variables include existing cognitive structure, psychological traits and personality attributes, and affective states.

The model implies that these variables dictate, either directly or by their interaction, the learning processes which occur. By learning processes is meant the particular strategies and the particular knowledge which are used, modified, or acquired. These learning processes bring about memory outcomes (changes to the learner's cognitive structure) which, in turn, determine performance, whether in response to cues such as questions or a test or as general behaviour in interaction with the environment.

Research data which can be interpreted in terms of such a model should provide useful insights on the process of learning. The present study was undertaken to obtain such data. Particularly, it was designed to test three hypotheses which, it should be noted, are of a very different type from those which are testable in large group experiments.

Hypothesis 1: For a given instructional programme, different learners will show similar general sequences in the development of their cognitive structure.

This hypothesis is tested by proposing a logical sequence of acquisition and linking of concepts, propositions, and rules and monitoring conformity to it.

Although the general sequence may be similar for all learners, prior knowledge might enable a learner to skip particular stages in the sequence or to acquire particular concepts, propositions or rules in a manner which has not been predicted; hence, hypothesis 2:

Hypothesis 2: Differences in the detail of cognitive linking sequences will be found. These differences may be due, in part, to differences in prior learning of the content material, but are independent of each individual's learning style.

Hypothesis 3: All subjects acquire intellectual skills by a learning process which involve a finite number of identifiable cognitive strategies.

It follows that diagnosis of a deficient strategy, followed by teaching to improve performance at the strategy, will assist progression through this or similar programmes.

DEVELOPMENT OF PROGRAMME MATERIALS AND BASES FOR INTERPRETATION OF DATA

The subject matter in the investigation centred on 13 skills in the field of genetics, which were obtained by deriving a learning hierarchy (Gagné, 1962) leading to the skill: "For a monohybrid cross involving an unmodified dominance/recessiveness relation between autosomal alleles, given selected phenotypes works out a valid genetic model consistent with the data."

Items to test each of the thirteen skills were then developed, and a set of fifty information statements necessary for the acquisition of the skills was prepared. The statements were organized in groups in an order consistent with a logical upward progression through the hierarchy. Each statement was written in a way which attempted to optimise its potential meaningfulness in terms of what had come before, and thus to optimise understanding.

Four theoretical bases for interpretation of data were prepared, and are summarised below.

1 Hypothesised model for the cognitive linking sequence. The hypothesised cognitive linking sequence is a step-by-step development of cognitive structure. The sequence leads to a final 'cognitive map' which is proposed to result from completion of the programme, and which is shown in Figure 2. This map is a network of proposition relationships between concepts and rules. The hypothesised sequence of development of this map guided the selection and timing of oral questions and written test items which the interviewer was to use, and served as a model against which the observed progression of each subject could be compared.

2 Test item procedural analysis. Each test item was examined to ascertain the logical, inferential, or conditional steps necessary in order to attain the correct answer with understanding. An example of a test item and the corresponding item analysis is given in Figure 3. These analyses were constructed in order to assist evaluation of each subject's manner of approach to, and progression through, the item. The analysis included classification of each step according to the cognitive strategies classification scheme which follows.

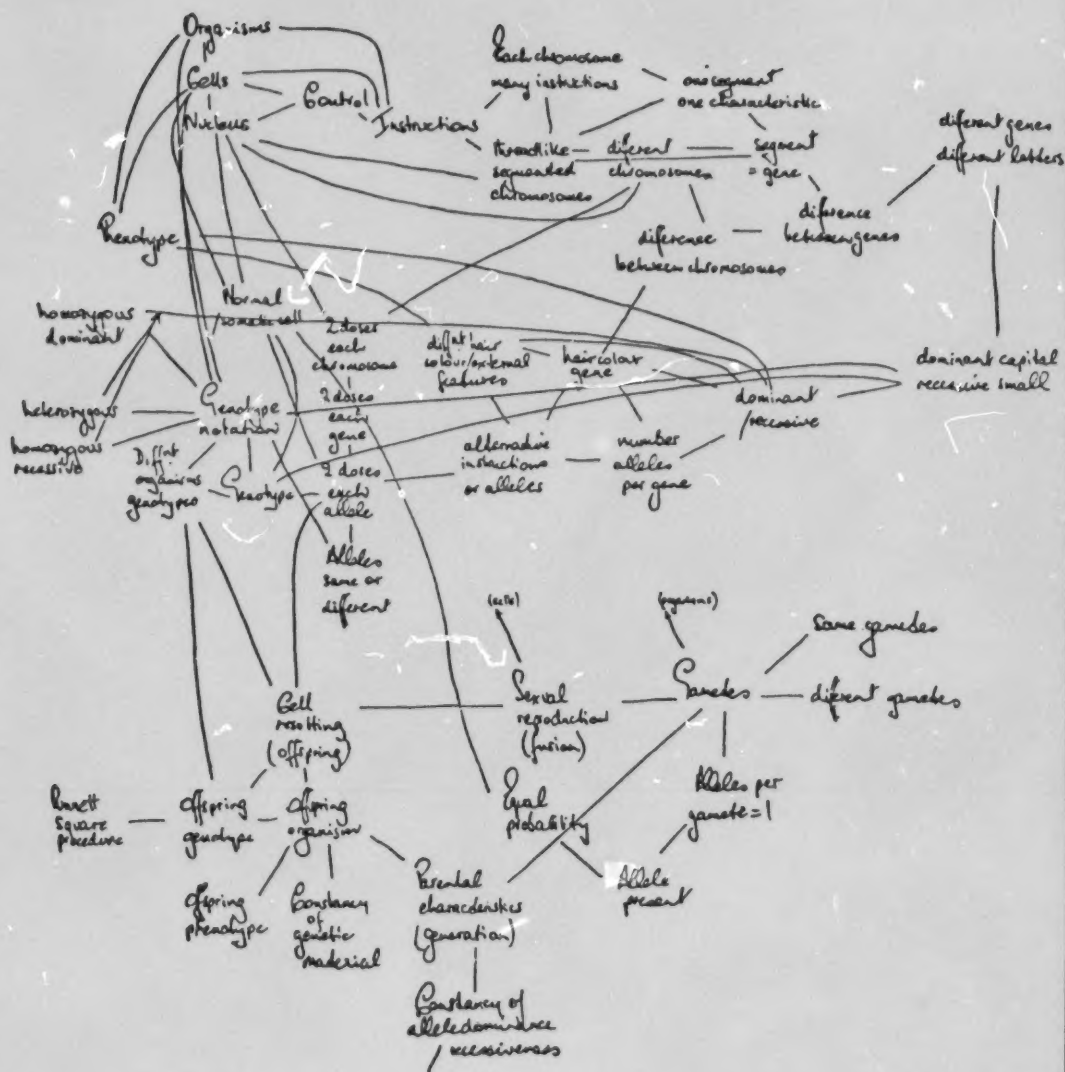


FIGURE 2: Hypothesised Cognitive Map at the
Completion of the Programme

FIGURE 3 - Sample Test Item and Item Procedural Analysis

Item

A spotted rabbit and a solid-coloured rabbit were crossed. They produced all spotted offspring. Assuming that these two traits are both expressions of the one gene, which trait is determined by a dominant allele?

Item Procedural Analysis

<u>Step No.</u>	<u>Core procedure (necessary for answer)</u>	<u>Cognitive strategy (ies) (see Figure 4)</u>	<u>Nature of step</u>
1		1, 2, 3	Chunks first sentence.
2		2, 3	Chunks second sentence.
3		6	Predicts spotted and solid-coloured to be alternatives/alleles.
4	*	6, 7	Confirms allelic association by interpreting first part of third sentence
5	*	4, 5	Establishes purpose: to decide which allele is dominant.
6		2	Concentrates on second sentence
7	*	6	Interprets second sentence in terms of dominant allele being expressed (information statement No. 35).
8	*	6	Deduces that spotted is dominant by over-riding uniform-coloured (obtained from information statement No. 18).
9		9.1	Notes that information is consistent with information statement No. 50.
10	*	8, 10	Confirms consistency of logic, accepts and writes answer.

3 Classification scheme for cognitive strategies. Substantial progress in promoting learning with understanding would be achieved if it were possible to identify and classify particular cognitive strategies needed by learners. Such identification would aid diagnosis of missing, deficient, or inappropriate strategies which might then be remediated by appropriate teaching. A tentative cognitive strategy classification scheme is outlined in Figure 4.

FIGURE 4 - Tentative Classification Scheme for Cognitive Strategies used in Learning Written Information with Understanding.

(Note: Each classification category is envisaged as having both cognitive and affective elements).

Strategy No.	Description
1	Scan communication <u>en bloc</u> - establish semantic sense and extent of meaningfulness against known.
2	Identify discrete areas of communication. Select one/more for attention.
3	Search to discriminate and confirm meaning against known of:
3.1	concepts
3.2	concept relationships (propositions)
3.3	skills
	contained in area of communication.
4(If required)	Establish that question asked (of a problem) is appropriate to, and consistent with, the nature of the communication. Confirm purpose as relevant and consistent.
5	Selectively order different parts for processing. Hold/manipulate multiple bits of information.
6	Process (apply knowledge of concepts, rules, skills, etc.) discriminated parts against known to generate new concepts, propositions, rules, etc.
7	Process discriminated parts against each other to generate new concepts, propositions, rules, etc.
8	Trial/rehearse logic and results of 6 and 7. Confirm consistency and logic.
9	Evaluate; extrapolate boundaries; draw implications.
9.1	Establish boundaries, conditions of validity and appropriateness. Extended by asking 'What if?....' questions (reflective thinking type); generalise; induce, etc.
9.2	Relate to real world and invoke episodic recall, analogies, etc.
10	Accept (affective) and incorporate (cognitive) new evaluated elements into structure. If necessary, delete old superceded structure.
10.1	Accept and incorporate received elements.
10.2	Accept and incorporate elements internally generated by strategies 6 - 9.
11	Utilise new structure elements appropriately and proficiently in place of old.

4 'Stages of learning' classification scheme. A tentative scheme for the identification of three sequential stages of learning, which lead to the consolidation of understood information into the learner's cognitive structure, is presented in Figure 5. This scheme was designed to promote informed assessment of the level of performance of the learner, in order that appropriate teaching strategies to facilitate progress might be instigated.

PROCEDURE

The learning task was administered individually to three subjects: subject 1 is male, aged 34; subject 2 is female, aged 34; and subject 3 is female, aged 20.

Relevant prior knowledge of the student and various affective variables, including attitude to this type of task, degree of anxiety, and other conflicting drives which would reduce attention and perseverance, were checked prior to commencing learning. Some training was given in verbalisation to encourage the subject to attend to meaningfulness of the material, connections with other things, images formed, and episodes remembered.

In the programme, information statements were presented to each subject in groups, and the appropriate test item given upon completion of each set.

Each student then proceeded through the programme with assistance given by the interviewer only when required. Information regarding the learning process was obtained from tapes of their progressive verbalisation as they attempted each information statement and test item, from their answers to oral questions used to diagnose understanding of various key concepts and concept associations, from written responses to questions and test items, and from their oral responses to diagnostic teaching of problem areas.

RESULTS OBTAINED AND INFERENCES DRAWN REGARDING THE LEARNING PROGRAMME

Full transcripts of the tape recording resulting from each interview were prepared. Each transcript was compared with the hypothesised cognitive linking sequence, the sequence of stages taken in each test item was compared with that hypothesised to be logical, and a search was made for instances of particular stages of learning. Observations and inferences were made regarding the use made of images, episodes, and analogy, the effects of prior learning on performance, the stability of certain links acquired during the programme, and the extent to which the learner extrapolated from information given and related information to personal experiences and the real world.

If learning were recorded in terms of the outcome measure of acquisition of each of the thirteen intellectual skills, each subject would be recorded as successful. However, how each subject learned, what and how much each subject knows, and for how long each subject will know it, are less clear but certainly more variable and individual.

Evidence obtained indicated the presence of two quite dissimilar styles for processing incoming information, with each subject routinely applying one or other of the styles. One style, shown by subject 2, is described as contextual rationalisation. This style is evidenced by continual elaboration or extension of the information provided, by a process of inter-relating and rationalising in terms of prior knowledge and the 'real world'. The aim appears to be not only to acquire the understanding of the material based on its logical internal consistency, but also to actively compare, check, and interpret each piece of information in order to rationalise this information in terms of its perceived context in the life experiences of the subject.

FIGURE 5 - Tentative Classification Scheme for Stages of Learning,
Leading to Understanding of Effectively-Consolidated Material.

Stage I: Limited/inadequate discrimination and processing

IA. Reception of part or all of the communication but without adequate discrimination of parts. Evidence of minimal chunking and inadequate structuring of the communication. Inability to proceed with processing because of inability to define the most appropriate starting point. (If this part is picked out for him, he may then proceed correctly, therefore the problem is in the subject being 'fazed' by the content, rather than inability to function at higher levels.). Need to virtually 'start again'.

Cognitive Strategies involved: Inadequate application of Strategies 1 - 3.

IB. Preliminary, and possibly confused, attempts at structuring the communication. Repeated and changing attempts at chunking, or limited and superficial processing. Perhaps lack of understanding of one or more parts, or of inadequate discrimination of this part relative to others. Perhaps 'skimming over' the information and gaining an inadequate understanding of the meaning of the communication.

Cognitive Strategies involved: Deficiencies in Strategies 1 - 5, leading to inadequate/incorrect use of 6 & 7.

Stage II: Progression to completion of content-specified processing

IIA. Structuring of the communication achieved, but evidence of conflict either between information and known, or within information. Conflict possibly due to previous misconceptions or inadequacies in cognitive structure. Repeated stopping and consideration, leading to possible frustration as attempts are made to rationalise and establish compatibility of disparate elements.

Cognitive Strategies involved: Unsuccessful resolution of strategies 6 & 7.

IIB. Resolution of major ambiguities or conflicts; realisation that processing has resulted in satisfactory conclusion.

Cognitive Strategies involved: Application of 6 - 8. Possibly some use of strategy 9.

Stage III: Acceptance and consolidation stage

IIIA. Evidence of instability (lack of consolidation) of cognitive structure. Application of learned information still not proficient; need for referral back to information, reworking of links, and re-establishing boundaries. Acquisition superficial, and performance sometimes faulty because of inappropriate use of concepts, forgetting of nature of links, reversion back to a misconception or element of previous cognitive structure, etc.

Cognitive Strategies involved: Revision, reworking of 6 - 10, perhaps involving 9.

IIIB. Stable acceptance and understanding of information. Use of material with proficiency and confidence. Consistent cognitive framework to serve as base for extrapolation and transfer.

Cognitive Strategies involved: Coordinated application of 6 - 11 to embed information by linking information with various sections of cognitive structure.

The alternative style of processing is called content-prescribed analysis. This style, while involving most or all of the logical, effective processes for analysing, interpreting, and evaluating a communication, is fundamentally restrictive and limited to the boundaries of the communication. Continual, active link-forming or extrapolation beyond the boundaries is not central to this style. This style was shown by subjects 1 and 3.

Generally, the results supported hypothesis 1, in that the general pattern of linking for each subject was consistent with the hypothesised model. It appears that such differences as were observed are a reflection of prior learning not only in the content area, but also more importantly in the learning style of the subject. Hypothesis 2, however, is contradicted by this result, as it proposed that differences in learning style would not be responsible for differences in sequence and pattern of linking. Prior construction of a theoretical cognitive linking sequence by a teacher should assist in assessing a learner's cognitive style, general level and nature of understanding, and particular misconceptions and difficulties, which in turn should form the basis for the implementation of appropriate teaching strategies.

With respect to the Cognitive Strategies classification scheme and the Stages of Learning classification scheme, evidence was obtained which supported inclusion of all the major categories in both schemes, and which supported the usefulness of both schemes in evaluating a subject's learning style and stage of progression towards consolidated understanding of the material. This evidence supports hypothesis 3.

Cognitive strategies exhibited by each subject provided the basis for inferences regarding learning styles considered above. The common occurrence of strategies incorporating inquiry, analogy, episodic memory, extrapolation, and evaluation (particularly strategies 8, 9.1 and 9.2) exhibited by subject 2, and the relative paucity of strategies 9.1 and 9.2 for the other two subjects, were particularly noticeable. The extensive supplementary teaching required by subject 3 could be interpreted as deficiencies in particular cognitive strategies. In fact, most of the teaching required was direct assistance with strategies 2, 3, 4 and 5. It also appeared that certain attitudes of this subject (a tendency to be 'fazed' by the material, and her overall lack of confidence) were related directly to such deficiencies.

One striking feature related to the Stage of Learning scheme, and shown by all subjects, was the difficulty in moving beyond Stage IIA if this stage involves a well-entrenched misconception. Each subject gave evidence of achieving Stage IIB -- III learning transiently, but then reverted back to application of the same misconception. It appears that effective deletion of prior misconceptions in favour of new knowledge constitutes an important strategy for progress in learning (strategy 10).

A further 'unstructured' task was given to subjects 2 and 3 three months after the initial learning programme. The primary aim of this task was to investigate the stability and generalisability of each person's cognitive strategies. Different requirements were placed on the subject to those of the initial programme: this time, the subject had to actively retrieve, organise, and use information already stored in memory. The task was a test of the accessibility and meaningfulness of this stored information.

In this task, which has similarities to those used by Champagne, Klopfer, De Sena, and Squires (1978) and Novak (1980), each subject was given thirteen small cards, on each of which was written a key concept or term from the original programme. The subject was then required to arrange the cards on a large sheet of paper in the way she considered the most 'logical or meaningful', and to connect the cards by arrows or in some other way to demonstrate relations between the terms. The original information statements were available to each subject throughout the task. After completion, the subject was required to explain each term and connection as clearly as possible. Having done this, the subject was then asked to describe as many external associations or meanings that this term had for her (i.e. connections which were unrelated to the descriptions already given).

Performance of each subject on this task again demonstrated a marked qualitative difference in modes of thinking and in learning outcomes. Subject 2, who demonstrated the contextual rationalisation style of thinking at the initial task (which we will call here Style I) again employed processes of extending, interrelating, interpreting, criticising, and rationalising. This style, which incorporated a preponderance of images, episodes, sensory and illusory links, analogies, and other relations with the real world, continued to be productive and effective. In Mayer's (1975) terms, she has a memory structure with a high degree of external connectedness. This memory structure appears to have been fabricated by long-term use of Style I thinking. By comparison, subject 3, who demonstrated the content-prescribed analysis style (called here Style II) at the initial task, exhibited a qualitatively different type of understanding. Her concept connection sequence was simple, basically serial, not very logically organised, and had remarkably few internal connections. Of the connections shown, many were questionable or incorrect. With one exception, she was quite unable to form any external connections with any of the concepts. It is tempting to conclude that, for her, the learning sequence was of little or no long-term value in assisting her to rationalise and react with knowledge of the world around her. Information from the initial programme appears to be in a form which is essentially unavailable for use under conditions where there is no specific, directed questioning.

In summary, two different learning styles, centred on different cognitive strategies, were shown in this study. Style I, which has similarities to Marton's (1975) deep-level processing, and Pask's (1976) comprehension learning, appears to involve active processes of relating and rationalising which are not basically dictated by task instructions. Style II appears to be more task directed, and is more limited to responding appropriately to received prompts and stimuli and to obtaining 'correct' answers to questions asked. It is conceivable that any learner may have both these learning styles available to be used at any time, but that the learner may routinely apply one style in preference to the other. Each individual's learning style appeared to be reasonably constant over time and task, but this disposition to use one style may be strongly influenced by various attitudes to learning generally, or to this 'school-type' of learning in particular. A similar effect has been reported by Marton and Säljö (1976), indicating that learning processes and outcomes are a function of the learner's conception of the task requirements.

There certainly appear to be significant differences in the nature and degree of understanding achieved by application of one or other of these styles. Understanding resulting from Style I may be more accessible and useful to the subject in everyday situations, whereas the understanding resulting from Style II is less related to other knowledge, less accessible, and potentially less useful.

It is quite possible that Style I is more difficult to acquire than Style II, and it appears that it is not emphasised normally in schools. Gunstone and White (1980) have demonstrated the lack of command of various learned physics concepts in a situation where the student was required to apply the material to a real world situation.

The theoretical bases of this study appear to be useful for identifying changes in cognitive structure of, and strategies employed by, a learner as he or she progresses through an intellectual skill learning sequence, and for formative evaluation of progress and performance for concept and skill acquisition and retention. Particularly, aspects of this study provide a framework for the diagnosis and remediation of missing, inefficient, or inappropriate cognitive learning strategies. If it is agreed that the learning style designated as Style I is a desirable one, it may be possible to teach explicitly the strategies appropriate to this style, and to foster attitudes which encourage students to adopt these strategies.

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THE USE OF COGNITIVE MAPPING IN TEACHING AND LEARNING STRATEGIES

Peter J. Fensham, Jan Garrard and Leo West

INTRODUCTION

Sutton (1980) in a recent review of research techniques for probing the organisation of a learner's prior knowledge has pointed to the limitations of these techniques when it comes to their use in the classroom as part of the science teacher's repertoire. He concludes, however, that some techniques do seem to be feasible although more work needs to be done on their use and usefulness. In general, Sutton's approach in this review is to see how a bridge can be built between the burgeoning interest among science education researchers in these techniques and science teachers who may wish to check periodically on their teaching and to remedy lack of preparedness in their students.

Novak (1980) and a number of his co-workers have suggested that there is a further bridge worth exploring. This is the role of these techniques as a recurring part of the learner's repertoire. In other words, their role need not be restricted to the one-sided example of providing diagnostic or readiness information, but they can be an active component of the teaching/learning experiences that occur throughout a curriculum unit.

Stewart (1979), in a strident critique of the associative mapping procedures of such workers as Shavelson (1974) and Preece (1978), argued that, being epistemologically unsound, they cannot be useful in the teaching of science. This weakness derives from the absence of meaning and truth/falsehood for the associations. In science learning the links between concepts are precise propositional statements that have very definite meaning. In a second paper, Stewart (1980) outlined in some detail a number of very varied techniques which all do have propositional form and hence meet his criteria for potential usefulness. There is also a reference to his work with Enochs in which feed-back of the results of their analysis of biology students' structures was associated with improved learning.

Occasionally in their research papers (e.g. Sutton refers to "penny dropping") but quite often in conference exchanges, cognitive researchers report their impressions that considerable learning often takes place when they are collecting their data. Heffernan (1980) writes of the "ah-ha" response of learners in his exploration of levels of cognition and we (West and Fensham (1979)) have also observed the same response, sometimes after a "ah-ha" one as the students grope for words to express their stored knowledge.

All these research studies, with their focus on the learner's cognitive structure represent a major shift in the role and status they give to the learner in the educational process of science. We have earlier suggested some new objectives they raise for science education (Fensham (1980)). In this paper, we have attempted to continue the process started by Sutton and Stewart, that is, the research techniques are explored in terms of criteria that relate to their usefulness in the life of ordinary classrooms. The adaptation of one of these research approaches and its use in chemistry classrooms at year 11 will also be described briefly.

STAGES AND TASKS IN COGNITIVE STUDIES

The potential stages can be discerned in most of the research studies under consideration.

Stage I: Data Gathering In this stage the researchers elicit data from learners in the form of concept associations, sentences, propositional statements, or rank orderings of ideas within a given topic of science learning.

Stage II: Data Analysis Here the researchers organise these data into a variety of structural forms using various procedures that include coding, qualitative categorising, quantitative scoring, and dimensional scaling.

Stage III: Data Feedback The researchers report their organisation of data to the learners and/or to their teachers.

Not all the studies have included the third stage, but in principle it could have been done provided adequate explanation was provided for the meaning of the rather technical form in which the learners' data now existed.

The active participation of the learner is only required in Stage I of these research procedures. Furthermore, the sequence of the stages has been clear in most studies so that the learner drops out at an early point. Novak (1977) in a credo statement has argued for science teachers and learners to be made more aware of the processes whereby the knowledge they are teaching and learning has been invented. In some work (e.g. Symington and Novak (1980)) and in our own recent studies (West (1979)) the stages have been much more iterative and interactive for the learners.

In Tables 1(a) and 1(b) fourteen studies from this type of research are listed. Under the headings for Stages I and II, there is an indication of what seems to be the key (or most difficult) task (or its product) that is involved in that stage for the learner and the researcher respectively. The term in brackets under each task for Stage II indicates the technical type of analysis. Stage III is classified as "translation" or "direct" according to whether the organised form of the data would or would not require explanation to teachers and students.

The seven studies in Table 1(a) use tasks in Stage I that can be done by learners in a group or class situation. Those in Table 1(b) on the other hand, use a data gathering procedure which involves a learner individually and separately with the researcher. The researchers in this second type of studies often refer to their methods as "clinical" (Pines et al. (1978)) and pay tribute for this to Piaget although most of them have quite other than Piagetian views of learning.

Criteria for Classroom Use

If these research procedures (as stages or as a whole) were to become part of the regular pattern of teaching and learning in science classrooms, they would need to meet a number of criteria. In Table 2 we suggest some of these criteria.

TABLE 1 (a) - The Key Tasks in the Stages of Cognitive Structure Research

Research Reference	Stage I Data Gathering	Stage II Data Analysis	Stage III Data Feedback
1. Shavelson (1974)	Word Association	Digraphs (Numerical)	Translation
2. Stewart (1980)	Sentence Writing	Networks (Linguistic)	Translation
3. Gunstone (1980)	Sentence Writing	Pathways (Numerical)	Translation
4. Schaeffer (1980)	Defining	Categories (Counting)	Direct?
5. West (1979)	Card Sorting	Maps (Graphing)	Direct
6. Maskill & Pereira (1980)	Essay Writing	Digraphs (Linguistic, Numerical)	Translation
7. Champagne et al (1979)	Writing Descriptions	Categories (Qualitative)	Direct

TABLE 1 (b) - The Key Tasks in the Stages of Cognitive Structure Research

Research Reference	Stage I Data Gathering	Stage II Data Analysis	Stage III Data Feedback
8. West & Fensham (1979)	Interviewing	Categories (Numerical)	Translation
9. Osborne & Gilbert (1979)	Interviewing	Categories (Comparative Form)	Direct
10. Pines et al. (1978)	Interviewing	Categories (Qualitative Form)	Translation
11. Delacôte & Tiberghien (1980)	Lesson Transcribing & Interviewing	Case Studies (Comparative Form)	Direct
12. Brumby (1979)	Solution Articulating	Categories (Comparative Logic)	Direct
13. Lybeck (1979)	Solution Articulating	Categories (Comparative Logic)	Direct
14. Ogburn (1980)	Solution Articulating	Networks (Linguistic)	Translation

TABLE 2 - A Set of Criteria for the Use of Cognitive Structure
Procedures in Regular Science Classes

Type of Criterion		
(i)	Instructional Time	A significant but not excessive fraction of the available time
(ii)	Instructional Modes	Teacher behaviour that lies within the usual range for science classrooms in a given cultural context
(iii)	Intellectual Skills	Tasks that are within the abilities of teachers and students with brief instruction
(iv)	Reference Categories	Coding that relates to the existing knowledge or skills available to the teacher
(v)	Content Validity	The nature of the data and the steps in their analysis relate to the teacher's intended content
(vi)	Learning Promise	Evidence for, or perceived likelihood that learning will be helped

One of these, No. 5, we have labelled content validity. It is similar to the epistemological criterion used by Stewart to reject the associative procedures of Shavelson et al. However, in our criterion the authority is now the teacher and not a learning theorist or a philosopher of science.

Consequently, the learner task of associating concept words with each other, or words with symbols may not be rejected by all teachers. They may, however, reject it for various reasons which may include those of Stewart, but which may also relate to the unfamiliarity and apparent irrelevance of such an exercise in science lessons. For example, debate as a teaching/learning experience is rarely seen in science classes whereas it is common enough in English, or Social Studies. What, then, is important for this criterion is that Stage I and possibly Stage II are seen by the teacher as having a sufficiently direct relationship to the science content under consideration.

There are only a few examples (e.g. Enochs and Stewart above) where firm evidence for criterion (vi) is available, although we have already referred to a number of positive impressions among researchers. The study described in the last section of this paper is an attempt to check the evidence for this criterion.

Sentence and short essay writing are within the scope of many science classrooms although they have been allowed to decline in those schools where there has been excessive use of work cards, short answers and multiple choice items.

The skills in the tasks of Stage II present much more difficulty and most of them at the moment involve specialised techniques which it would be unreasonable to expect science teachers to acquire in general. Of those in Table 1; procedures 4, 5, 9, 11, 12 and 13 seem to be possible for teachers without serious modification. Numbers 7, 9, 12 and 13 include reference categories with names that are unfamiliar to teachers but these names are not essential to the coding. These tasks would thus also meet criterion (iv) whereas the categories used in Studies 4, 8 and 10, would not because of their technical nature.

Table 3 summarises, for the research procedures in the studies of Table 1, the application of these three criteria (ii), (iii) and (iv).

TABLE 3 - The potential for the use of cognitive structure procedures in science classrooms

(Instructional Modes versus Intellectual Skills criteria)

Stage I equivalent teaching mode	Stage II Possible skill requirements	
	Researcher or Science Teacher	Researcher only
Didactic	4	1, 2, 3, 6, 7
Discussion	12, 13	
Activity	11, 9	
Individualised	5	8, 10, 14

Criterion (i) is an empirical matter and can be adjusted by the teacher to some extent by spreading the tasks over the lessons of a topic. The time of data collection is not recorded as such in most of the research reports and almost certainly the data analysis was a longer process that would be slower still if it were to be shared with the learners or carried out by science teachers. This means that major modifications of most of the second stages in these research procedures are probably necessary.

Criterion (iii) refers to the intellectual skills and procedures involved in the data gathering and analysis. One of these (the particular response for the learners) obviously already meets the criterion. The corresponding researcher's task to elicit this response, however, often does not.

It has already been pointed out that the setting for the data gathering in the studies of Table 1(b) is not congruent with the teacher-centred classrooms that make up much of science education here and in most countries. Some of these individualistic procedures (e.g. 4 and 9) could, however, with some modification be more appropriate in activity-centred learning in laboratories and during classes with more individualised instruction and learning. It is, however, hard to envisage extended interviews, such as in studies 8, 10 and 12, ever being used in regular schooling. Science teachers who use class discussion could easily accommodate procedures like those in 7 and 11 that involve the comparison of short descriptions or explanations.

Apart from the setting, most science teachers are not accustomed (nor trained) to conduct interviews, to record and transcribe their classroom discourses or to conduct the systematic procedures that are involved in, for example, Studies 1 - 5 of Table 1(a). Most of these could be taught to use them fairly easily, but some forms of clinical interview are rather specialised (Studies 10, 12, 13) and probably lie beyond teachers unless extensively modified.

CONCEPT MAPPING IN A CHEMISTRY CLASS

West and Fensham (1979) had used a combination of several techniques in developing cognitive maps of first year chemistry students at university. It was decided that a modified form of this mapping might be possible in regular classroom work. One of the authors (P.J. Fensham) was the teacher of a year 11 high school class when they were beginning their systematic study of chemistry. The content of the first four weeks of this course will be readily apparent from three lists of important ideas in Table 4. These were shorthand for the set of propositions involving each that had been emphasised in the teaching of the course. They were to be the nodes of the cognitive map in the sense of West (1979) and Stewart (1980).

TABLE 4 - The sets of main ideas for each week of the mapping training programme

Week 1	Week 2	Week 3
Observation	Compound	Mole
Property	Element	Weight % Composition
Building Block	Qualitative Composition	Compound
Pure Substance	Symbolic Formula	Element
Material	Chemical Identification	C=12, Standard
Mixture	Values of Properties	Relative Atomic Mass
Separation	Building Blocks	Relative Molecular Mass

The training programme for the students was as follows:

Phase 1: At the end of week 1 the students completed a rating form for the degree of relationship between the 21 pairs of nodal ideas (10 mins.). They then identified which node they would associate with a list of the experiments, homework exercises, and actual chemicals and equipment they have used or been shown during the week (5 mins.). These data were then analysed and represented by the researchers as a two dimensional cognitive map which was returned to the students early in Week 2 and discussed with them (10 mins.). The students were then asked to try to write appropriate words on the linkage lines on their maps to describe the relationship they had perceived (10 mins.).

Phase 2: At the end of week 2, the students again completed rating and association forms for the nodes and learning experiences of that week (15 mins.). At the start of week 3, the students were taken step by step through the four rules that transform these data to a 6 level map (20 mins.). These were redrawn for optimal representation and handed back for the students to write on the relational descriptions and to add the associations of experience (20 mins.).

Phase 3: Near the end of week 3 the students were asked to list what they considered to be the key ideas of the week (10 mins.). Most of them (23 in all) listed more than half of the preselected list in Table 4, which was encouraging. The third list of ideas was then issued along with data sheets and a set of 8 instructions that lead to a completed map (10 mins.). The students were asked to complete the maps at home and return them after week 4 in which a test on the content of these first three weeks was held. The test included several items which were part of a modest evaluation of the exercise (criterion vi). These findings will be reported elsewhere (Fensham, Garrard and West (1980)).

The training programme occupied 110 minutes out of a total class time of 840 minutes. Its longest segment was 20 minutes, a not too unreasonable proportion of a 60 minute lesson. The slower students did not complete several of the tasks in the class time allowed. All found the describing of the maps' linkages difficult and these were nearly all uncompleted.

The instructions and work sheets seemed to be clear and readily applied by the students. In Phase 2, a number of counting errors were made and they were translated on to the maps. Nineteen of the students returned the third map on time although again a number of errors were found in their execution of the mapping steps.

SUMMARY

In this exercise the first five criteria of Table 3 were probably met. Our subsequent checks may enable us to claim that criterion 6 is also met, and there is little doubt that without it most chemistry teachers would remain sceptical about the worth of such an "extra" set of activities.

The exercise also indicates that it is possible with modifications to move research techniques like 5 and 8 in Table 3 into at least the realm of possibility of teacher-centred or didactic classrooms.

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LEARNING A PROCEDURAL TASK

Bill Butts

PROCEDURAL TASKS

A procedural task may be defined as one whose learning requires the integration of two kinds of human capability, intellectual skills and motor skills (Gagné, 1977). Parking a car, serving a tennis ball, and operating a videotape recorder are all examples of procedural tasks although their relative cognitive and psychomotor demands differ from one to another. In the early stages of learning such a task the emphasis is cognitive while the sequential rule or executive routine (Gagné, 1977) to be followed is learned and the component motor "part-skills" are recalled. Later motor skill becomes more important. Ultimately, practice, accompanied by feedback and any necessary correctives (Bloom, 1976) enables the part-skills to be chained so that the complete procedural task can be performed proficiently with little conscious effort on the part of the learner. Fitts and Posner (1967) distinguish three phases in the teaching and learning of such a task:

1 The Early or Cognitive Phase. Initially the emphasis is on gaining an understanding of the nature of the task. Instruction is provided in written or oral form, often accompanied by visual aids or by modelling. The learner's attention is directed to the proper sequence of actions and the external prompts which signal the start of each subordinate movement. Previously learned motor part-skills are recalled and sequenced as the executive routine is learned.

2 Intermediate or Associative Phase. Next the various part-skills which make up the overall motor performance are improved in precision, smoothness and timing and integrated to form the total motor performance.

3. Final or Autonomous Phase. Practice results in increased precision, smoothness and timing as the task comes to be performed autonomously and becomes less subject to interference from other ongoing activities.

Procedural tasks in the science laboratory

Science students are often required to learn to perform simple manipulative tasks and to operate a range of complex scientific equipment. They must learn the procedural tasks involved. Such procedural tasks may be as simple as filtering a suspension or as complex as dissecting a pregnant rat.

The influx of new and more complex science apparatus into secondary schools, which was stimulated by Commonwealth funding from the mid sixties, has increased markedly the range and complexity of procedural tasks which have to be learned in the laboratory. Ability to operate such items as the cathode ray oscilloscope, linear air track, pH meter, nuclear radiation scaler, polaroid camera and, more recently, the microcomputer, is expected of students in the relevant classes. If students are to learn to operate such equipment, it is important that their teachers be competent in its use. Institutions involved in the pre-service education of science teachers should accept the responsibility of ensuring that their graduates are proficient in the operation of as wide a range of such equipment as possible.

One way in which the pre-service institution can overcome the problems resulting from its students having diverse backgrounds in the operation of science equipment, is to provide self-instructional programs or modules which teach these procedural tasks, on demand. Such modules can be, and have been, designed and developed in many different ways ranging in sophistication from a simple printed instruction sheet to a multi-media package complete with slides, audiotape and motion picture film (Little & deM-MacLay, 1978).

But what is the most effective of the range of self-instructional modes available? Will some modes be differentially more effective for some students than for others? Can all learn equally well from the manufacturer's printed instructions or will some (or all) benefit from viewing an appropriately produced training film? How important is it to provide learners with an instructional mode of their choice? These questions were addressed in the study which is described in this paper.

COGNITIVE STYLE AND LEARNING A PROCEDURAL TASK

In order to achieve a larger student sample, the procedural task chosen was the operation of a 16mm motion picture projector rather than a piece of science equipment. While a projector is not specifically an item of science equipment, science teachers (as well as teachers in all other areas) could be expected to be proficient in its operation. Furthermore, the task is clearly a procedural one and has many characteristics in common with the procedural tasks involved in the operation of various kinds of science equipment in schools. One can at least speculate on the validity of generalizing from the results of this study to the learning of more science-specific procedural tasks.

The experimental investigation described here was a trait-treatment interaction study, which used the field-dependence-independence construct of cognitive style and the learner's preference for the instructional mode experienced as two learner traits likely to interact with one another and with the mode of self-instruction used, in order to affect learning outcomes differentially. Two outcomes were assessed: performance on the procedural task immediately after instruction and the learner's evaluation rating of the instruction received.

The field-dependence-independence construct of cognitive style (Witkin, Moore, Goodenough and Cox, 1977) was selected as a pertinent learner trait since it provides a basis of hypothesizing the instructional mode which would be expected to be most effective for learners at each end of this spectrum. Two factors likely to affect field dependents and field independents differentially, the structure and the degree of personalization, both of the learning environment and of the self-instructional materials, were considered in this study.

Field dependence-independence and self-instruction

As in their perceptual style, field dependent persons tend to accept the field as a whole, as it is given, rather than attempting to reorganize or restructure it. The word "field" in this context should be interpreted in a very broad sense to include not only the perceived physical environment, but also the provided instructional materials, the given data required for problem solving and even the social milieu (Harris, quoted in Witkin et al, 1977).

On the other hand field independents will impose their own structure on a field lacking organization and will restructure a field which was originally organized in a way they believe unsuitable for their purpose. This suggests that highly structured self-instructional programs which tell the learner exactly what to do at each step may be more effective for field dependents (Bien, 1974).

One way of relieving the learner of the task of extracting the critical aspects of the visual field presented to him in visuals (e.g. pictures) illustrating the learning task, is to highlight these aspects in some way such as by the use of out of focus backgrounds, simplified line drawings and so forth. Such techniques are referred to as "compressed visuals" and their effects on the learning of a procedural task have been studied by several investigators (Dickie, 1970; Hessler, 1973; Zaner, 1977). Zaner, for example, found that field dependents who used compressed visuals (line diagrams) to learn the operation of a videotape recorder performed better on the criterion measure (accuracy and speed in carrying out the procedural task) than field dependents who used the non-compressed visuals (colour photographs). Interestingly, field independents were debilitated by the use of the compressed visuals, scoring better if they had used the self-instructional program containing the coloured pictures.

Field dependents and field independents differ in their social orientation to life in general, at least as far as interpersonal relationships are concerned. Field dependents are sensitive to the prevailing social frames of reference and tend to conform to them. Field independents are much less sensitive to the social climate and tend to function autonomously, in isolation from its dictates. It may be expected then that field dependents and field independents would respond differently to individualized self-instructional learning environments. Field independents could be expected to adapt to the impersonal nature of the situation more readily than field dependents who may feel ill at ease in the absence of social interaction with other learners and without an instructor to guide them, especially if there is ambiguity in the learning task (Brooks, 1976). Self-instruction may, in fact, be somewhat inappropriate for field dependents. If they are forced into this instructional mode, making the cue presentation (Bloom, 1976) as personalized as possible can be expected to appeal to, and hence affect positively, the learning outcomes for field dependents. One way of personalizing a self-instructional presentation is to utilize modelling, presented on film or videotape. Such a method of cue presentation could be expected to be differentially effective for field dependents, as has been shown in a number of studies (Koran, 1969; Salomon, 1974; Marantz and Dowaliby, 1973a, 1973b).

Three self-instructional modes were employed in the present study, (a) modelling, presented by means of an 8mm sound/colour film, (b) a synchronized tape/slide presentation and (c) an illustrated "print and picture" instruction manual. In terms of both structure of the learning materials and their degree of personalization, it was argued that mode (a) would be most appropriate for field dependents and mode (c) least appropriate. The visual and verbal content of the three modes were, as far as possible, identical, except for motion and the incorporation of the face of the instructor in the modelling presentation. This mode also incorporated some "visual compression" by use of a zooming technique to highlight certain aspects of the presentation of the modelled operation.

Field-dependence-independence and learner preference

The second learner trait considered in this study was the learner's preference for instructional mode. Educational philosophies often assign a significant role to student choice in deciding both what is to be learned and how it is to be learned. The arguments seem to embody the empirical assumption that the learner will learn more if he studies by a method consistent with his preference (Cronbach and Snow, 1977). But how valid is this assumption? The empirical evidence is conflicting. Some studies support the assumption (Kress and Gropper, 1966; McLachlan, 1969; Dorsel, 1975), others do not (James, 1962; Tobias, 1973; Didcott, 1972; Liao, 1969 and Janoscrat, 1976) while some even suggest that learning is enhanced if instruction is in a non-preferred mode (Yelvington, 1968; Annis, 1976). Some studies have shown that while learning by one's preferred mode does not increase cognitive achievement it does lead to more positive attitudes (Duncan, 1972; Pascal, 1971). While "...the evidence discourages the romantic view that self selection of the instructional diet pays off" (Cronbach and Snow, 1977, p. 478), this learner trait was focussed on in this study since it was hypothesized that it would interact with cognitive style to influence both cognitive-psychomotor and affective outcomes. Specifically it was hypothesized that receiving one's preferred mode would become less important as field independence increased.

Many other learner traits are likely to affect outcomes in this learning situation. Motivation to learn the procedural task involved is an obvious one. However, given the sample size available only two additional learner traits were able to be taken into account as likely to influence learning outcomes. These were intellectual ability (defined here as grade point average) and fine motor ability (Fleishman, 1956). Both were controlled statistically in the study.

THE HYPOTHESES TESTED

Seven hypotheses were formulated, four of them concerned with the ability of the learner to perform the procedural task immediately after instruction and three with his/her evaluation rating of the instructional program after instruction. Whenever performance was the dependent variable, intellectual ability and motor ability were statistically controlled. Three hypotheses posited direct relationships between selected outcomes and (a) instructional mode (b) cognitive style and (c) preference for mode experienced.

Specifically it was postulated that:

1. Students instructed by the modelling mode would out-perform students instructed by the other two modes, on the criterion task;
2. Field independents would out-perform field dependents on the criterion task;
3. Learners who received instruction in their preferred mode would evaluate the instructional program more highly than learners who received instruction in other than their preferred mode.

Four trait-treatment interaction hypotheses posited relationships between either performance or evaluation rating and the interaction of field independence and instructional mode or of field independence and instructional mode preference. Specifically it was hypothesised that there would be statistically significant relationships between:

4. Performance on the procedural task and the interaction of field independence and instructional mode, such that field dependents would be favoured by learning from the modelling mode;
5. Performance and the interaction of field independence and instructional mode preference, such that field dependents required to operate in a non-preferred mode would be more adversely affected than field independents;
6. Evaluation rating of the instructional program and the interaction of field independence and instructional mode such that field dependents following the modelling mode would rate the program more highly than those following the "print and picture" mode;
7. Evaluation rating of the instructional program and the interaction of field independence and instructional mode preference such that field dependents required to follow a non-preferred mode would rate the program less favourably than if they followed their preferred mode.

THE DESIGN

The subjects for the study were 151 undergraduate students in the third year of a concurrent B.A., Dip.Ed. program at Macquarie University. They were training to teach either in the primary school or in the secondary school in the subject areas of English, History, Librarianship, Mathematics, Modern Languages, Science or Social Science. None had had any previous experience in the operation of a motion picture projector. Each was tested individually for cognitive style using the Embedded Figures Test (EFT) (Witkin, Oltman, Raskin and Karp, 1971). Three subscales of the Minnesota Accuracy and Speed Test (Briggs and Tellegen, 1971) were used to assess fine motor ability. These were (a) the "large peg placement test" of manual dexterity; (b) the "nails pick-up test" of finger dexterity and (c) the "hole total test" of arm-hand steadiness (Fleishman, 1956; Cronbach, 1960). Students were also asked to rank, in order of preference, five different instructional modes for learning the procedural task. As well as the three actually used in the study, individual instruction by a tutor and printed but unillustrated instructions were included. It was argued that these five modes formed a spectrum in terms of degree of personalization of the instructional program.

Having completed the above tests and instructional mode preference questionnaire in the initial session, each student returned individually to undertake the mode of instruction allotted. Stratified random assignment (Cronbach & Snow, 1977) to the three instructional modes was based on EFT score and instructional mode preference. Immediately following instruction the learner was asked to evaluate the instructional program on a ten item semantic differential instrument in which were embedded four pairs of bi-polar adjectives ("good-bad", "valuable-worthless", "important-unimportant", "successful-unsuccessful") associated with the Evaluation factor (Feise, 1969). The sum of the scores on these four scales was taken as the evaluation rating of the instructional program.

As soon as the evaluation instrument was completed the learner moved on to undertake the performance test. No free time was allowed in order to avoid, as far as possible, the effects of mental practice (Beasley, 1978). Thus the study focused mainly on the learning occurring in the first phase of the Fitts-Posner model (1967).

In the performance test the subject was handed a short 16mm film and asked to project it, in focus, on a screen conveniently located near the projector. When this was accomplished successfully, the testee was asked to perform certain directed operations, such as reversing the film and showing a single still frame on the screen. The entire test operation was recorded on videotape. To determine a performance score for each subject this videotape was analysed in detail following a protocol which enabled the assessment of (a) accuracy (lack of errors and omissions and adherence to the prescribed sequence) (b) smoothness (absence of "stalls" and "baulks") and (c) speed (time to perform certain specified operations). This is in line with Gagné (1977) who points out that "observable degrees of precision, smoothness and timing" characterize skilled performance of a motor task. Standard scores (z-scores) on each of the three aspects of performance were summed with appropriate weighting, to provide the subject's final performance score.

THE RESULTS

A multiple regression model was used to test each of the seven hypotheses in the study (Nie, Hull, Jenkins, Steinbrenner, and Brent (1975)). An F test (Kerlinger and Pedhazur, 1973; p. 178) was used to determine whether the proportion of the variance accounted for by the variable(s) in focus in each hypothesis was statistically significant (at the 0.01 level). Table 1 summarizes the findings. It will be seen that only two hypotheses received empirical support. Neither was a trait-treatment hypothesis.

The major findings of the study, which also incorporate other data gathered during instruction, were:

1. Field independent students took less time to complete instruction, required less assistance and performed better on the performance test than did field dependent students, irrespective of the mode of instruction used.
2. The three instructional modes were equally effective for all students, after controlling for intellectual and motor ability.
3. Neither cognitive style and instructional mode nor cognitive style and instructional mode preference interacted to affect either performance or evaluation rating of the program to a statistically significant extent.
4. Obtaining one's preferred mode of self-instruction did not affect scores on the performance test but did result in one evaluating the instructional program more positively.

Thus the study failed to identify any significant trait-treatment interactions associated with cognitive style. However, field independents did consistently out-perform field dependents when tested after instruction on the procedural task. This suggests that either field dependents have greater difficulty in learning the task or they have greater difficulty in learning it in a self-instructional setting. Perhaps they would perform as well as field independents if both were instructed in a small group context, where the social interaction would be more conducive to a field dependent learner.

TABLE 1 - Summary of multiple regression analysis of results

Hypotheses	Dependent Variable	Independent Variable in Focus	% Variance accounted for by this independent variable	F	P
1	Performance	Instructional mode	1.0	(2,146)=0.78	>0.01
2	Performance	Field Independence	11.8	(1,147)=20.6	<0.01
3	Evaluation rating	Mode preference	4.6	(1,149)=7.2	<0.01
4	Performance	Instructional Mode X Field Independence Interaction	1.5	(2,143)=1.28	>0.01
5	Performance	Field Independence X Instructional Mode Preference Interaction	0.1	(1,145)=6x10 ⁻⁴	>0.01
6	Evaluation rating	Field Independence X Instructional Mode Interaction	0.7	(2,145)=0.53	>0.01
7	Evaluation rating	Field Independence X Instructional Mode Preference Interaction	1.0	(1,147)=1.57	>0.01
-	-	Intellectual ability	0.00		
-	-	Motor ability	4.1	(1,149)=6.1	>0.01; <0.05

Group vs self instruction of the procedural task

In an attempt to resolve this issue a small scale follow-up study was conducted. All students in the Mathematics, Science and History subject areas of the same teacher education course the following year were tested for field-dependence-independence using the Group Embedded Figures Test (Witkin, Oltman, Raskin and Karp, 1971). The twenty most field dependent and the twenty most field independent students were allocated randomly to two treatment groups and given instruction on the same procedural task as

previously. One group learned the task individually following the "print and picture" self-instructional program used in the earlier study. The second group was divided into four sub-groups of five students - two sub-groups containing field independent students, the other two field dependents. Personalized instruction was provided to each of the four sub-groups by a tutor who involved all learners in part of the actual operation of the projector being studied. Testing procedures were as in the major study but were delayed until one week after instruction.

Analysis of variance showed that, once again, field dependent students, no matter whether they were instructed in small groups or had followed a self-instructional program, did not perform as well as field independents. Mean group scores (summed z-scores) on the performance test are given in Table 2.

TABLE 2 - Group means on performance test

	Field Dependents	Field independents
Self		
Instruction	-2.90	4.48
Group		
Instruction	-4.90	3.33
Total	0.00	

Again no interaction between this cognitive style and mode of instruction which affected the measured learning outcome - performance on the target procedural task - was observed.

CONCLUSION

The results of these studies indicate that the operation of a 16mm motion picture projector can be taught as effectively by means of an appropriately designed illustrated instruction manual, the "print and picture" mode, as by an expensive mediated presentation or by small group instruction. If the results can be generalized to learning the operation of other items of audiovisual equipment, or even of science equipment, they suggest that considerable savings can be made by utilizing the simplest of self-instructional procedures.

Throughout these studies field independents consistently out-performed field dependents on the criterion task-operating the motion picture projector. This may have little relevance to the design of programs appropriate for teaching pre-service science teachers the operation of laboratory equipment, since such people are likely to be highly field independent. However children in school science classes range from highly field independent to highly field dependent and the latter group can be expected to experience difficulties in learning the procedural tasks associated with many science activities. More investigation into ways of compensating for these difficulties is needed.

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TOWARD A THEORY OF LEARNING IN TERTIARY SCIENCE EDUCATION

Howard Fearn-Wannan

EARLY STUDIES

Early attempts to build a theory of learning in tertiary education have been hampered by a lack of insight in several key areas. Firstly, researchers have tended, by and large, to take a univariate approach to the question, isolating individual predictors which were not necessarily linked causally with the outcome variables. Furthermore, there appeared to be an air of disappointment and frustration about attempts to understand the nature of learning and to predict successfully. Anderson's (1970) statement that "trying to account for academic performance is like trying to nail red-currant jelly to a wall" is well-remembered. It seems that what was being overlooked was the fact that human behaviour is a multivariate phenomenon, and that successful mode-building requires a global approach. It must be borne in mind that academic outcome variables are likely to be accounted for in terms of arrays of independent causal variables, each contributing to a greater or lesser extent, to the total variance in the criterion.

A second serious problem amongst the early studies was the failure to recognize the importance of non-cognitive influences upon students' academic behaviour. Lip-service was paid to the view that characteristics such as achievement motivation were significant influences, but they were never seriously considered in such theory-building, presumably because of the lack of reliable measures of such qualities.

Thirdly, many early workers studied the student in vacuo, ignoring the influences of the educational context. Whilst it is true that workers like Astin (1968) looked at the role of insitutional characteristics, they were never considered in relation to the students' characteristics, but only as isolated variables.

THEORETICAL FRAMEWORK OF PRESENT INVESTIGATION

As long ago as 1935, Lewin (1935) expressed the view that human behaviour is a function of the characteristics of the person and the characteristics of the environment in which that person operates:

$$\text{i.e. } B = f(P, E)$$

where B = Behaviour
 P = Personal characteristics
 E = Contextual characteristics.

The field theory of Lewin was interpreted by Murray (1938) in terms of student needs, and an environment which serves to satisfy or frustrate these needs. Since the time of Lewin and Murray, workers in many fields have made efforts to view human behaviour from this transactional perspective. Grinker (1956), for example, interpreted therapeutic processes in Psychiatry in terms of transactions, and Kelly (1966) has used this framework to redefine Psychopathology.

The person-environment model came into prominence as a theoretical frame-work for educational research when Cronbach (1957), in his presidential address to the American Psychological Association, encouraged educational psychologists to conduct investigations to find aptitude-treatment interactions. A similar model of the teaching-learning process is founded upon the concept of social interaction. Smith (1960) conceived the teaching-learning process as a series of interactions between the educator and the learner such that the learner perceives the educator in terms of his own peculiar personality structure. (i.e. through his own eyes.)

This present research investigation considers the student in terms of his learning characteristics and his academic self-concept. The learning environment, on the other hand, is seen as a set of mediating influences bearing upon the student from family, peers and lecturers. The outcome variables are classified as mediating outcomes (e.g. test-anxiety) and a final outcome (academic performance). These variables are set up in the form of a causal model which attempts to show the logical interrelationships amongst its component variables. Figure 1 shows the general causal model which forms the theoretical framework of this investigation.

The general causal model shows sex (i.e. femininity) as the initiating variable to the whole system. The theories of Freud (1929), Mead (1949), and the observations of researchers such as Mehrabian (1953) and Veroff et al. (1958), suggest that sex plays a dominant role in determining a variety of human personality factors and perceptions. The placement of this factor as the "spring-board" of the model is soundly based from both the theoretical and practical points of view.

PRACTICAL PROBLEMS

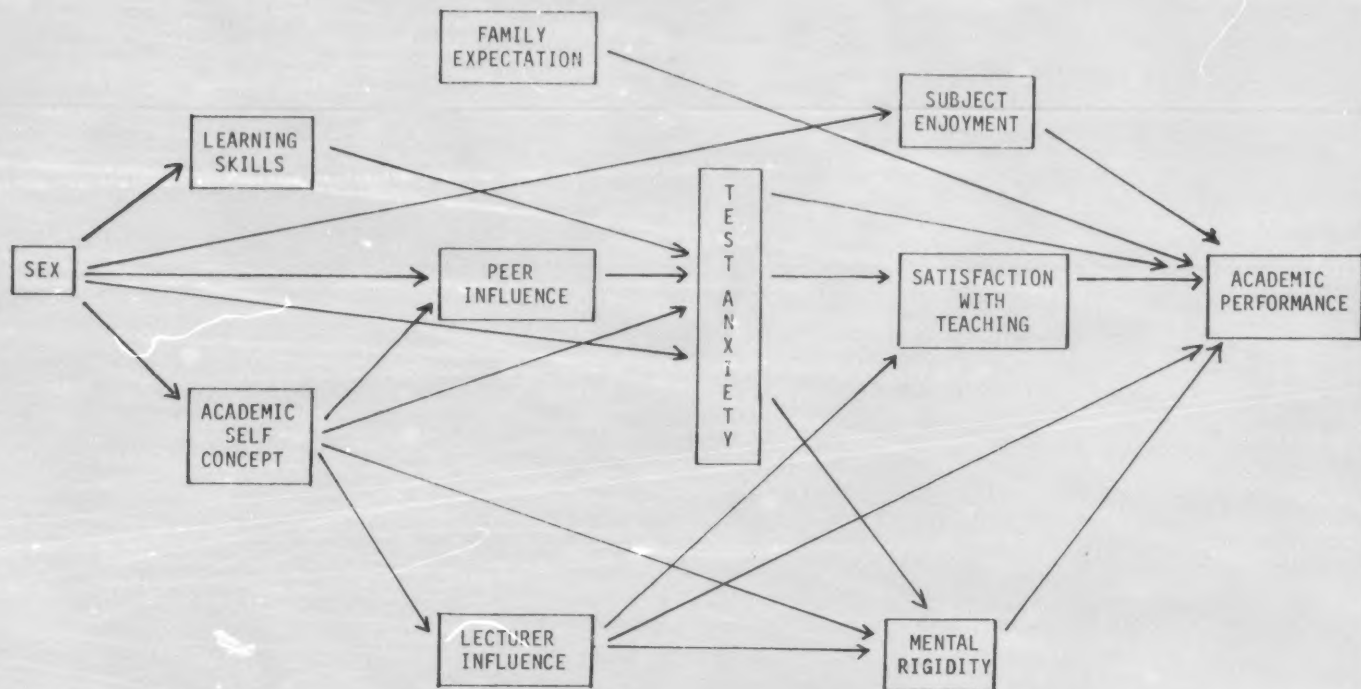
1. Measurement of Variables. Scales for the assessment of many of the component variables in the model shown in Figure 1 had been developed earlier (Fearn-Wannan, 1979), but some new scales, e.g. Family Expectation, Learning Depth, Subject Enjoyment and Mental Rigidity were developed for the purpose of this investigation.

As in the earlier studies, the procedure for scale development was as follows:

- (a) generation of a pool of appropriate items for each scale
- (b) validation by panels of judges
- (c) selection of items which have high judge-agreement indices
- (d) subjection of selected items (comprising trial scale) to a group of students
- (e) factor analysis of scores on these trial scales
- (f) final selection of items with similar factor structure
- (g) assessment of the reliabilities of the final scales.

2. Lecturer Co-operation. One of the persistent disappointments of eager researchers is the lack of co-operation by some tertiary lecturers who decline to make their classes available for testing. The researcher cannot force students to submit to the testing procedure, and unless lecturers assist researchers by making complete class populations available, the researchers will be forced to rely upon the relatively few students who are willing to co-operate in such testing, and thus his sample is biased in favour of such testophiles. The researcher in higher education still has a considerable credibility problem (born of prejudice) amongst academic staff in general and until this is overcome such investigations will continue to be difficult.

FIGURE 1 - General Causal Model of Performance in Higher Education



3. Results. Recent analyses of data drawn from the R.M.I.T. sample have given relatively consistent models (within courses) each of which explain more than 40% of the criterion variance. For example, let us consider the academic performance of the group of 90 students in first year Applied Biology at R.M.I.T. in 1980. The results of these analyses are set out in Table 1 and in Figure 2.

Sex, the primary variable in this model, exerts a minute direct effect, but displays a wide range of indirect effects. Personality measures show substantial direct effects with a fairly wide, but modest, range of indirect effects, while the students' perceptions of their learning environment in general have small direct effects, with very limited indirect effects.

The roles of text-anxiety and satisfaction with teaching as mediating variables are confirmed by the analysis, several of the causal variables exerting indirect effects upon academic performance via these variables. (See Table 1)

Table 2 sets out a comparison of the direct effects of selected variables from the model for both 1979 and 1980 data. The similarity of pattern is obvious.

It should also be pointed out that even across course groups, there have been striking consistencies with respect to the influence of certain variables upon academic performance at first year level. For example, models developed for Librarianship, Food Technology, Medical Technology and Applied Biology have consistently demonstrated the strong influence of achievement motivation upon academic performance, with path coefficients ranging from 0.24 to 0.32. The personality characteristic of non-involvement also stands out as a consistent diminisher of academic performance, with path coefficients ranging from -0.17 to -0.31. A learning skill factor which has consistently emerged across course groups is listening recall, with path coefficients ranging from 0.20 to 0.39. Lecturer student-orientation (0.00 to 0.22), assertiveness (-0.15 to -0.38), inspiration (0.19 to 0.39), peer group friction (-0.15 to -0.18), and test-anxiety (-0.12 to -0.32) also display consistency. Bearing in mind that a path coefficient of 0.5 represents an effect accounting for 25% of the criterion variance, it can be seen that some of these effects are relatively "bright stars in the multivariate sky".

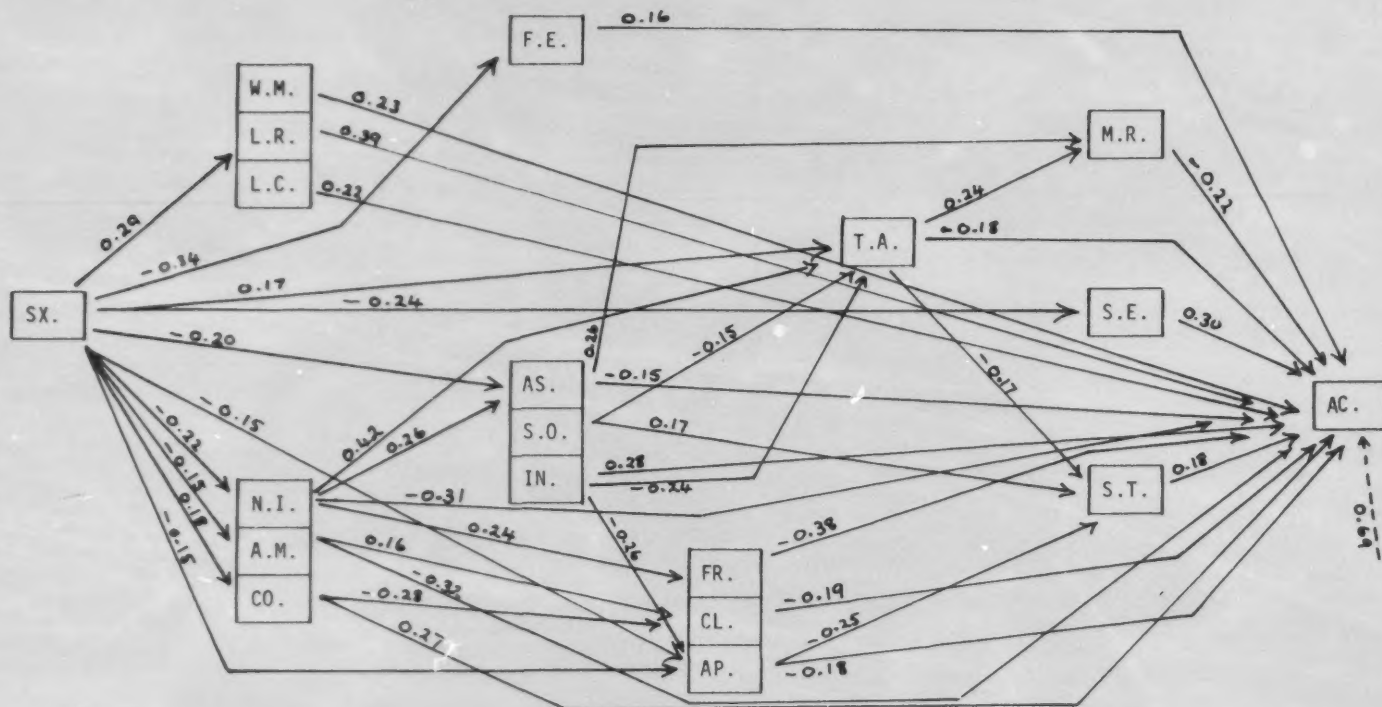
Two of the variables in the original hypothesized model, viz. student learning depth, and peer group intimacy fail to maintain their places in the model when the criterion for inclusion is that the direct effect of the variable should account for at least 2.25% of the variance (i.e. $p > 0.15$). Thus the method of model analysis can be used to prune out the weak elements of the model, leaving reasonably influential components only. Although learning depth had shown promise in some of the early studies, e.g. Ramsden (1979), it failed to register any significant effect in the models described in this research. Similarly, peer group intimacy (Walberg, 1969) failed to gain inclusion in the causal models.

4. Deficiencies of Causal Models. The causal models hypothesized in this study have been assessed using path analysis as a statistical means of assessing the relative influences (if any) of the various elements of each model. These relative strengths are expressed as path coefficients which are estimated, using multiple regression analysis, on the assumption that there is linear relationship between each pair of dependent and independent variables in each model.

TABLE 1 - Direct and indirect influences on academic performance

<u>CAUSAL VARIABLE</u>	<u>INDIRECT EFFECTS VIA</u>															<u>DIRECT EFFECT (β)</u>
	L.R.	N.I.	A.M.	CO.	F.E.	AS.	S.O.	IN.	FR.	CL.	AP.	T.A.	M.R.	E.S.	S.T.	
SEX	0.113	0.068	0.048	0.049	0.054	0.030	-	-	-	-	0.024	0.031	-	0.072	-	-0.042
N.I.					0.030	0.039	-	0.050	0.067	-	0.056	0.076	-	-	-	-0.310
A.M.						0.029	-	0.078	-	0.030	0.026	0.059	-	-	-	-0.317
CO.					0.026	0.023	-	0.109	-	0.053	0.046	-	0.033	-	0.043	0.286
AS.											0.058	0.068	0.057	-	-	-0.151
S.O.												0.027	-	-	0.031	0.010
IN.											0.042	0.043	0.059	-	0.074	0.282
W.M.												0.027	0.035	-	-	0.227
L.R.															0.032	0.391
L.C.																0.218
F.E.															0.032	0.163
FR.															0.045	-0.380
CL.																-0.193
AP.															0.045	-0.162
T.A.												0.053				-0.178

OUT



See Appendix I for variable code.

TABLE 2 - Direct effects of selected variables in the academic performance models of first-year biology students at R.M.I.T.
(comparison of 1979 and 1980 data)

VARIABLE	1979 data	1980 data
Work Methods	0.194	0.227
Listening Recall	0.225	0.391
Conscientiousness	0.118	0.286
Non-Involvement	-0.274	-0.310
Achievement Motivation	0.410	0.317
Assertiveness	-0.161	-0.151
Student-Orientation	0.080	0.010
Inspiration	0.247	0.282
Friction	-0.252	-0.380
Cliqueness	-0.124	-0.193
Apathy	-0.160	-0.162
Test Anxiety	-0.126	-0.178
Total Accounted Variance	43%	52%

Now it is known that this is a false assumption because earlier analyses (Fearn-Wannan, 1979) demonstrated that curvilinear relationships are common amongst these variables. Curvilinear path analysis involves much more complex mathematics than linear path analysis, but it is the author's intention to attempt to build such curvilinear models in future research, hopefully giving a more realistic understanding of the problem. Such a refinement can wait, however, until the major groups of personal and environmental influences have been identified, and the general structure of the model is reasonably clear.

5. Current Investigation. Early impressions given in the academic prediction literature suggested that intellectual differences amongst students in higher education are minimal and should not, therefore, be regarded as of any great significance in attempting to account for variance in student performance. The corollary of this proposition is that cognitive characteristics are of little value as predictors, at least at undergraduate level. Accordingly the attention of some researchers has been directed toward the non-cognitive field as a source of variance amongst tertiary students which would help to account for the observed variance in their academic performance.

As was stated earlier, the learning models described above, which are the product of several years of investigation, have failed to predict with more than a 50% accuracy, despite the fact that most of the promising, recognized categories of non-cognitive variables have been investigated.

Consequently, attention is now being directed back to the cognitive domain of intellectual activity (e.g. Chiapetta, 1976), with a closer look at differences amongst students with respect to the higher Piagetian categories of thinking. Research currently in progress is looking at the influence of the higher mental abilities, and these will be integrated into the model as personal characteristics.

CONCLUDING COMMENT

A generalized learning model for science education in the tertiary field is being developed, and the proportion of performance variance accounted for is rising as the model is being refined.

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APPENDIX I - Variables in the person-environment interaction model
of academic productivity

PERSONAL VARIABLES

SX. = Sex (Male = 1, Female = 2)
N.I. = Non-Involvement
A.M. = Achievement Motivation
CO. = Conscientiousness

STUDY SKILLS

W.M. = Work Methods
L.R. = Listening Recall
L.C. = Listening Comprehension

PERCEIVED LECTURER CHARACTERISTICS

AS. = Assertiveness
S.O. = Student-Oriented
IN. = Inspiration

PERCEIVED PEER GROUP CHARACTERISTICS

FR. = Friction
CL. = Cliques
AP. = Apathy
F.E. = Family Expectation

OUTCOME VARIABLES

T.A. = Test Anxiety
M.R. = Mental Rigidity
S.E. = Subject Environment
S.T. = Satisfaction with Teaching
AC. = Academic Performance

LEARNING OR COGNITIVE STYLES - WHAT ARE THEY?

Margaret Brumby

INTRODUCTION

Over the last few years interest in the outcome of learning, either the quantity (Bloom, 1956) or of the structure of knowledge attained (Ausubel, 1968; Gagné, 1977) - i.e. what students learn, has been paralleled with interest in the actual processes, used by individuals to produce this outcome - i.e. how students learn. This led to the need to develop more personal methods of observation. Various groups of researchers developed quite different learning tasks, and collected their observations in the students' own words (either in written form, or during individual interviews). It quickly became apparent that there were qualitative differences in the way individual students approached a particular learning task, and the term 'learning style' (with synonyms 'cognitive style' and 'cognitive strategy') was coined to embrace these differences.

Many dichotomies have been published, which on close examination seem to fall into two sets:

1. The student's perception of the task

There are two important criteria which dichotomies in this set have in common:

- (i) immediately breaking a task or topic into its component parts, and studying them step-by-step, as discrete entities, in isolation from each other and from their surroundings. In this category Witkin's 'field-independence' (Witkin et al., 1977), Pask's 'serialist' (Pask and Scott, 1972), Bruner's 'analytic' (Bruner, 1960; Thorsland and Novak, 1974) and possibly Guilford's 'convergent production' (Hudson, 1966), all have, as their essential criterion, a 'divided into parts' view. (Skinner's model of S-R learning steps also suggests this approach to learning.)
- (ii) an overall view, or seeking the topic/task as a whole, integrating and relating its various subcomponents, and seeing them in the context of their surroundings. In this category are the corresponding pairs to those listed in (i) above: Witkin's 'field-dependence', Pask's 'holist', Bruner's 'intuitive' and possibly Guilford's 'divergent production'. (This category echoes much of the early 'Gestalt' theories.)

Most workers suggested that their dichotomies were equivalent in rank, i.e. one did not necessarily result in greater learning.

2. Level of integration

The other common set of criteria, embracing the remaining dichotomies are:

- (i) a memorizing approach, with poor ability to integrate or relate new material into a student's own existing knowledge. In this category are Wertheimer's 'rote-memorizing' (Wertheimer, 1945) Ausubel's 'rote-learning' (Ausubel, 1968) Marton's 'surface-processing' (Marton and Saljo, 1976) and Pask's 'operation learning' (Pask, 1976).
- (ii) active integration of, or relating new material to students' existing knowledge (which, by implication includes the real-world). The corresponding pairs are Wertheimer's 'productive thinking', Ausubel's 'meaningful-learning', Marton's 'deep-processing' and Pask's 'comprehension learning'.

These 'level' dichotomies were clearly hierarchical, i.e. it was better to be one than the other.

All workers have concentrated on rather singular, but individually widely different methods and types of data collection. Subtle differences may well be artefacts due to narrow sets of observations.

On the basis of small number of students, and narrow data collection, all have generalised. None of these workers seem to have identified which part of the learning process they were actually investigating. Dahlgren and Marton (1978) stated: 'All the dichotomies seem to relate more or less directly to two different conceptions of learning, namely learning as a transmission of unrelated "bits of knowledge" on the one hand, and learning as a change in one's conception of some aspect of reality on the other'. If this view is initially accepted, i.e. that these dichotomies are essentially all describing one intellectual skill, which for simplicity is termed 'cognitive or learning style' then one point of confusion still exists. Interpretation of observations has been made on differing, implicit assumptions as to how many styles may be possessed by an individual.

The following alternatives have all been implied:

1. There is a single cognitive style, existing as a bipolar spectrum, in which individuals may be consistently placed (i.e. it is stable);
2. There are different styles, but an individual only has one, independent of the task (i.e. it is a mutually-exclusive characteristic of the student);
3. There may be only one, or more than one style, the individual can select the one appropriate to the task;
4. There are two separate styles, and both can be present in individuals in different degrees.

This paper describes my extension of these studies into a biological framework, in Britain during 1979.

METHOD

Development of the task

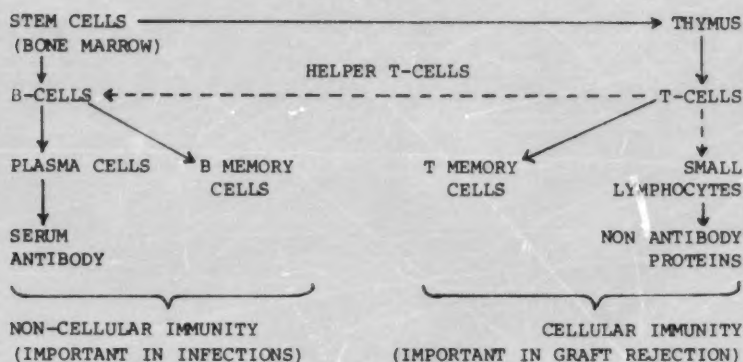
In order to explore possible variation in learning style for a biological task, an unfamiliar descriptive task was developed.

During the earlier studies investigating misunderstandings of the concept of Darwinian evolution, held by first year Biology students, there occurred frequent misuse of the term 'Immunity'. This latter topic is not part of the standard A-level biology syllabus, and upon checking, only four students were found to have formally studied Immunity previously. This was therefore excellent topic to use to design an unfamiliar problem for these students; it is an active part of biological research today, and students were extremely interested after discussing common misunderstandings of evolution. A 'concept map' of Immunity (based on Ausubel, 1968) was prepared for overhead projection. (Figure 1). To remove all need for 'memorising', this diagram remained on view throughout the task.

Task implementation

The 48 first-year Human Biology students participated in this task in place of a lecture. The following instructions were given before they saw the diagram itself:

FIGURE 1 - The Immunity Task
THE IMMUNE RESPONSE



'I'm going to show you a diagram of the main types of cells involved in Immunity. I want you to study the diagram for a few minutes in order to sort it out in your own minds, and then, when I tell you, I want you to write out your own explanation of Immunity, in your own words, as clearly as you can.

The diagram will be on view all the time - this is NOT a memory test! The relationship between various cells is shown by arrows. Solid arrows in general represent the transformation from one type of cell to another. There are two dotted arrows which represent a relationship which is, as yet, not completely understood.

I will not speak, or answer questions once the diagram is on, as I don't want to focus your attention in any way.'

The diagram was then shown, and after two minutes they were allowed to begin writing. The written descriptions took 20 minutes to complete.

Method of analysis

The broad ideas of Pask's serial/holist dichotomy and Marton's deep/surface levels of processing were used to develop criteria appropriate to analyse this task. Sample analyses based on Pask's and Marton's criteria were also undertaken by two independent judges. The following terms and relevant criteria were agreed upon:

1. Perception of the task.

Students varied in the way they perceived the diagram. Some immediately broke it into two vertical columns, others saw the diagram as a whole. The following specific criteria were used:

Analytic (A): where the order of two or more points corresponded to vertical progression through the map, a letter 'A' was placed in the margin.

Holist (H): where two cells were compared laterally across the map, or one sentence contained points from both types of immunity, the letter 'H' was ascribed. Occasionally a level comparison was contained in two succeeding sentences, within the one paragraph. These were also classified as 'H'. Thus by adding the marginal letters, students could be categorised into three groups:

- A: Using analytic style;
- H: Using holist style;
- A + H: Using a mixture of both styles (termed 'versatile').

2. Level of Integration

The content of this task was new to all but four students. Students' protocols, however, revealed that, although they had not formally studied this topic before, many students actively added extra detail, knowledge, examples and hypotheses to their 'descriptions', linking this diagram to their existing knowledge. Where students did this, a '+' marginal note was used, and they were classified as 'high' in their level of integration for this task. Other students did not give any additional information or interpretation, or relate the diagram to their existing knowledge in any way, but described only the explicit points of the diagram. They were classified as 'low' in their level of integration.

Using these two separate sets of criteria, all 48 students' protocols were analysed, and the results tabulated. Examples of student's protocols are included in Appendix I.

RESULTS

TABLE 1 - Distribution of Learning Styles and Levels of Integration

LEVEL	LEARNING STYLE			TOTAL
	ANALYTIC	HOLIST	VERSATILE	
HIGH	9	1	11	21 (44%)
LOW	15	3	9	27 (56%)
TOTAL	24	4	20	48
%	(50%)	(8%)	(42%)	(100%)

From Table 1 it is clear that, for this task, just over half of the students were classed as low level, and just under half at high level of integration. Table 1 further shows that within the two basic styles identified for this task (analytic, holist), half of all participating students described this task in a purely analytic way. A second large group showed features of both styles and were classed as versatile.

Further points of analysis:

1. Gaps

A further interesting point arose when protocols were examined for 'gaps' - i.e. arrows or cells which were entirely omitted from students' descriptions. It was striking that none of these gaps occurred in any analytic description. Another gap was the arrow linking stem cells to B-cells directly. A third gap was the omission of any mention of memory cells (i.e. the most central part of the diagram).

2. Misconceptions

Not all students who showed a high level of integration made biologically correct links to their existing knowledge. Some students called B and T cells 'blood' and 'tissue' cells; others explained stem cells as 'red blood cells with nuclei'; non-antibody proteins were postulated to be 'enzymes'. These mistakes may be instances of the development of misconceptions, postulated by Ausubel (1968) and West and Fensham (1974).

3. Familiarity with topic

The four students who had studied immunity previously were placed into the high level of integration. In their styles two were versatile and one each was H, and A.

4. Possible sex difference

A difference was found between the proportion of male and female students using different styles. Approximately 30% of all male students, and 60% of all female students in the student population, used a purely analytic style in their descriptions. Such a difference was not significant in the group of versatile students (using a mixture of styles), 39% of all females and 47% of all male students showing versatility in their perception of this task. Numbers in the holist style were too low for comment.

DISCUSSION

This descriptive task, using visual-verbal translation, was a straight-forward task similar to common methods of summarising topics in science subjects. Student interest in the topic itself was high, and the time and industry with which they participated, suggested they did not consider it obscure, irrelevant or tedious. It resulted in a spectrum of student descriptions. A single dichotomy (such as Pask's or Marton's) was inadequate to analyse all individual protocols. By combining elements of both these worker's criteria, however, a distinction could be made between learning style (identifying analytic/holist) and levels of integration (identifying low/high).

Category of perception for this task

The students classed as using an analytic style essentially saw the diagram as two vertical columns, with a minor column in between. Many emphasized this point by ordering their description numerically. But this was not NECESSARILY a 'sparse mental picture', or 'isolated topics' which Pask used to define 'operation learning'. These results highlight the difference between Pask's earlier 'serialist' and subsequent 'operation learner'. Students classed as analytic did not NECESSARILY 'keep to the surface of the topic, without relating to meaning' as in Marton's 'surface-processing'. Conversely, students classed as holist for this task explained by moving laterally at each level of the diagram, drawing comparisons and discussing points more generally. However this style did not NECESSARILY include further insight than was contained in the diagram.

Similarly students who were versatile (i.e. used characteristics of both styles) did not NECESSARILY go beyond the specific content of the diagram. It is difficult to imagine how Marton would classify either these versatile students who showed only low level of integration, or analytic students with high integration.

Interestingly, students who left 'gaps' in their descriptions were classed as either holist or versatile. No analytic student omitted any points on this diagram.

Levels of integration used in this task

Three qualifications should be recorded, concerning the categorization into low and high level of integration:

1. Students classed as 'low' may have considered the question only required this level, and may, if specifically directed, have been able to show a high level of integration.

2. 'Levels' may be content-dependent to a much higher extent than are learning styles.
3. By definition, 'levels' would not be revealed by nonsense tasks (e.g. Pask) or very simple tasks (e.g. Witkin), which have no relation to a student's pre-existing knowledge.

These levels of integration were quite distinct from, and independent of, the style used by students at different levels. In this analysis those four students, known to have formally studied this topic previously, were not excluded. Such an occurrence of a diversity of educational backgrounds, experience and interest may always exist in student populations participating in research. In higher education this tendency will increase in future, both as schools gain increasing autonomy, and as tertiary entrance requirements become less rigid.

IMPLICATIONS

Several questions emerged from this preliminary study:

1. How stable is a student's individual learning style? If this task were repeated some weeks later, would students repeat these observations? Do students vary their style for different concepts within a discipline?
2. Can learning style (or cognitive strategy) be considered an intellectual skill? In discussing the relationship between memory structures and learning outcome, Gagne and White (1978) reviewed and defined intellectual skills as 'the concepts and rules that are defined as the memory structures that make possible rule application ... i.e. the learned capability of "knowing how"'. The definition of learning style as the student's perception of a task/topic fits within this general description.
3. If learning styles may be considered as intellectual skills, then how many can an individual student have? The results of the Immunity task support Thorsland and Novak's (1974) hypothesis that the two kinds of learning styles are independent, and both may be present in the versatile student.
4. Is the 'level of integration' significantly different from learning styles? Or are these dichotomies different observations of learning styles in operation obtained by other methods of data collection?

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APPENDIX I

EXAMPLE 1: Analytic style, high level of integration

- A(B) 'Non-cellular immunity is the way in which antibodies in the blood can fight infection. Stem cells in the bone marrow mature and give rise to B-cells. These are released into the bloodstream and circulate in the plasma. When a foreign body, such as bacteria, is encountered, plasma cells manufacture antibodies which can specifically act on and destroy the bacteria. Once this specific antibody is made, a feedback mechanism works, so that the B-cells can "remember" the mode of manufacture of the specific antibody, and this is stored in the B memory cells for future reference.
- +
+
+
+
+
+
- A(T) Cellular immunity is the response of the body to foreign tissue such as grafts and transplants. Stem cells from the bone marrow can act upon the cells of the thymus gland which produce T-cells. T-cells are transformed by an unknown mechanism to small lymphocytes which are within the lymphatic system. The lymphocytes encounter foreign protein such as a skin graft, and build up proteins which adhere to the foreign protein, preventing cell replication. Again, once the protein has been built up, a feedback mechanism works on the T-cells and the mechanism of manufacture of the protein is "remembered" in the T-memory cells.
- +
+
+
- 3rd column There also seems to be a correlation between B cells of non-cellular immunity and the T-cells of cellular immunity.

EXAMPLE 2: Holist style, low level of integration

- 'Two different routes to explain the immune response. Taking the stem cells (for example) going in one way through to thymus cells, and in the other to bone cells. In the process they have a common type of memory cell, perhaps because of helper T-cells being between, but in the end give different results. The thymus cells will be important for graft rejections, and the bone cells will end being important for infections.'
- H
H
H

EXAMPLE 3: Versatile, low level of integration

- 'This diagram shows two types of immunity, cellular immunity resulting from non-antibody proteins, and non-cellular immunity resulting from serum antibodies. In both types of immunity the cells producing it arise originally from stem cells in the bone marrow. In the case of cellular immunity, the stem cells develop in the thymus and then into T-cells which form the small lymphocytes of the blood, producing non-antibody proteins. For non-cellular immunity the stem cells develop into B-cells which in turn form the serum antibody-producing plasma cells of the blood. It is thought that B-cells may also be formed from T-cells by way of another type, called helper T-cells. The B and T cells also form B and T memory cells, these however do not have a direct role in the immunity of either type.'
- H
A(T)
A(B)
3rd column
H

DEVELOPMENT OF A SCALE OF COGNITIVE DEMAND
FOR ANALYSIS OF PRINTED SECONDARY SCIENCE MATERIALS

John Edwards and Gloria Dall'Alba

INTRODUCTION

Science teachers rely heavily on printed materials as the bases for their teaching programs. As a result, the informed selection and/or development of such materials is a crucial part of the science teacher's role. Most teachers have not been trained for such a role, and there are few instruments available to help the teacher generate meaningful insights.

Eraut et al. (1975) reviewed the schemes available for analysis of curriculum materials. Of the few schemes available, most produce a time-consuming analysis in the form of a general overview. In contrast, techniques such as those employed by Bormuth (1967, 1971, 1973), Clarke (1973), Shayer (1970, 1972, 1974), Ingle and Shayer (1971) and Klopfer (1971) reveal the benefits that can come from a focussed, detailed analysis.

This paper describes the development of another focussed instrument. The focus in this case is on cognitive demand, and the aim was to produce an instrument readily usable by classroom teachers. It was planned that the instrument would allow the teacher to analyse the cognitive demand suggested by the objectives, made by the learning tasks, and evaluated by the evaluation instruments or techniques. The internal consistency, with respect to cognitive demand, between these three major curriculum components would be revealed by such an analysis. Gagné and Briggs (1973) point out that 'it is necessary to achieve internal consistency among (these) three important components of instruction'.

THE CONCEPT OF COGNITIVE DEMAND

The concept of cognitive demand developed in the study has several facets. These were derived from a detailed review of a range of learning theories. Those that most influenced the dimensions of the derived definition were : Bloom (1956), Bruner et al. (1966), de Bono (1976), Gagné (1970), Taba (1962, 1967), and the interpretation of Piaget in Novak (1977), in ASEP (1974a), in Karplus (1977) and in Ausubel et al. (1978). This review was conducted in constant interplay with the isolation and classification of the cognitive demands made on students in commonly-used secondary science texts and curriculum project materials.

No single theory of learning was found to be adequate to allow the articulation of a definition of cognitive demand. Each theory reflected some distinctions but failed to account satisfactorily for others perceived to be of importance. This is in agreement with the conclusion reached by Bloom (1956) when attempting to construct the Taxonomy of Educational Objectives - Cognitive Domain.

We were reluctantly forced to agree with Hilgard (1948) that each theory of learning accounts for some phenomena very well but is less adequate in accounting for others. What is needed is a larger synthetic theory of learning than at present seems to be available.

(Bloom 1956, p.17)

In the absence of an adequate theory, the concept of cognitive demand developed in this study drew threads from a range of theorists. Such an approach may be criticised on the grounds that 'we cannot legitimately work in the framework of one theory and then invoke principles and concepts that are derivative from another theoretical framework' (Novak in Tamir, 1980, p. 152). Tamir's response to this criticism by Novak is relevant to the approach adopted here, particularly in the absence of a single, adequate theory. He says :

Perhaps when one deals with a highly formal discipline this (Novak's) argument is valid. Yet, even physicists find it possible to work simultaneously within the framework of two alternative theories, wave theory and particle theory. Education is a practical discipline, much richer than only one theory can encompass. The art of the eclectic is the one that helps educators in seeking and obtaining the best guidance in each particular event.

(Tamir 1980, p.152)

Some dimensions of the concept of cognitive demand were readily distilled from their original source, while others required the drawing of inferences which are extensions of the ideas advanced by the theorists.

The Definition of Cognitive Demand

In this study, cognitive demand is defined as the demand which is placed on cognitive abilities, through the dimensions of :

- (i) complexity - the nature of the sequence of operations which constitutes a task, that is, the nature of each component operation and the links between operations (after Bloom, 1956);
- (ii) openness - the degree to which a task relies on the generation of ideas (after de Bono, 1976 and Taba, 1962);
- (iii) implicitness - the extent to which the learner is required to go beyond data available to the senses (after Bruner, 1966 and Bruner et al., 1966); and
- (iv) level of abstraction - the extent to which a task deals with ideas rather than concrete objects or phenomena (after Piaget in Karplus, 1977 and Novak, 1977).

The level of cognitive demand of a task is determined by the interaction of all of its dimensions. Whilst the dimension requiring the highest level of cognitive demand is the principal factor in determining the overall level of cognitive demand, the remaining dimensions may create a context which raises or lowers the cognitive demand level.

PROCEDURE

Developing a Scale of Cognitive Demand

The Scale of Cognitive Demand was derived from an analysis of a representative cross-section of junior secondary science texts and units. All learning tasks in the cognitive domain were extracted from the objectives, learning tasks and evaluation items. This resulted in the identification of eighty-seven tasks. Clarification and definition tasks were then ranked in order of increasing cognitive demand according to the cognitive demand construct described in the previous section. The tasks appeared to fall into six distinct groups, corresponding to six levels of cognitive demand. The original task types can be seen in Table 1.

TABLE 1 - Cognitive Demand Scales

<u>GROUP 1</u>		<u>GROUP 4</u>	
1.1	Recall or memorise specifics	4.1	Understand and apply a model of an abstraction
1.2	Simple measurement	4.2	Internalise a concept
1.3	Observe	4.3	Calculate
1.4	Repeat	4.4	Apply a rule or principle
1.5	Collect and organise information	4.5	Compare on stated criteria
1.6	Simple comparison	4.6	Classify
1.7	Simple classification	4.7	Extrapolate
1.8	Simple grouping	4.8	Extract relevant, explicit criteria
1.9	Simple seriation		
1.10	Simple recording		
1.11	Follow a simple set of laboratory instructions		
<u>GROUP 2</u>		<u>GROUP 5</u>	
2.1	Recall or memorise procedures, difficult rules or principles	5.1	Construct a representation
2.2	Demonstrate use of measuring equipment	5.2	Develop an abstract concept
2.3	Understand a direct, physical model	5.3	Generate relevant criteria
2.4	Simple extrapolation	5.4	Generalise
2.5	Plot	5.5	Hypothesize
2.6	Translate	5.6	Isolate variables
2.7	Summarise	5.7	Design an experiment or piece of equipment
2.8	Observe with discrimination	5.8	Isolate inferences or assumptions
<u>GROUP 3</u>		5.9	Integrate
3.1	Relate	<u>GROUP 6</u>	
3.2	Develop an operational definition or simple concept	6.1	Link a model with reality
3.3	Simple application	6.2	Assess the impact
3.4	Simple hypothesizing	6.3	Evaluate
3.5	Complete an experimental design		

Application of the Scale of Cognitive Demand

The Scale of Cognitive Demand is used to determine the cognitive demand levels of the objectives, learning tasks, and evaluation, and to allow a comparison between these.

Three major issues associated with practical usage of the scale needed to be clarified: The sampling procedure; a procedure for unitising; and the categorisation procedure. Unitising refers to the process of separating materials into tasks or units of analysis (Shapiro 1974).

The ease of categorisation and unitising were both investigated through the tryout described in the next section. The suggested unitising procedure involved the use of units created by changes in task type. When analysing any section of material, no new categorisation is made until there is a distinct change in task. Isolating distinct tasks is generally straightforward for objectives and evaluation. Reference to the definition and examples for each task type was the suggested basis for categorisation.

The sampling procedure used is that recommended by Babbie (1973), a systematic sample with a random start. A number between one and ten is randomly chosen, then a systematic sample is taken depending on the number of pages in the material under study. Appropriate sampling fractions for different sized texts were determined by comparing different sized systematic samples. The Wilcoxon matched pairs signed-ranks test (Siegel, 1956) was used to determine whether there was a significant difference between the frequency of occurrence of each cognitive demand level for the different sampling procedures. If the samples were not significantly different it was concluded that the smaller sample size was adequate. Once the minimum appropriate sample was determined, two samples of this size were compared using the two-tailed form of the Kolmogorov-Smirnov test (Siegel, 1956). This statistic determines whether there is a significant difference between two cumulative distributions and thereby tests whether the samples have been drawn from different populations. Use of this statistic provided a further check on the representativeness of the sample and hence the adequacy of the sample size.

The threat of bias due to periodicity (a cyclical pattern in the materials that coincides with the sampling interval) was investigated. While for the materials analysed in this study periodicity was not a problem, potential users are alerted to this possible problem in the introduction to the instrument.

Tryout of the Scale of Cognitive Demand Instrument

A pilot trial of the instrument was conducted by the authors and a lecturer with broad secondary science teaching experience. This involved analysing a cross-section of science materials, to check the clarity and comprehensiveness of the instrument and to rectify any minor faults. As a result, modifications were made to the instrument prior to teacher trialling.

Seven trial teachers were each asked to analyse one set of materials they were currently using. As well, four of the teachers were asked to analyse the core material of 'Cells, the Units of Life' (ASEP, 1974b). This was used to establish inter-rater reliability both of unitising and categorising. The teachers were also asked to comment on the usefulness and usability of the instrument.

Intra-rater reliability was assessed by one of the authors doing two analyses, separated by one month, of the core of ASEP 'Cells, the Units of Life'.

The reliability of unitising was calculated using the formula:

$$C.R. = \frac{2M}{N_1 + N_2}$$

where M is the number of units on which the analysts agree, and N_1 and N_2 refer to the number of units isolated by analysts 1 and 2, respectively.

(Holsti, 1969).

Categorising reliability depends on the categories and the analysts. It is '...largely a function of category definition and the types and numbers of discriminations to be made', in addition to the analysts' ability to use the categories accurately (Holsti, 1969, p.136). Scott (in Holsti, 1969) developed an index of reliability, pi , which is based on C.R., the coefficient of reliability used for unitising. As Holsti notes, 'by chance alone, agreement should increase as the number of categories decreases' (p.142). Scott's index incorporates observed agreement but also corrects for the number of categories and expected chance agreement. The formula for Scott's pi is:

$$pi = \frac{Po - Pe}{1 - Pe}$$

where Po is percentage observed agreement between two judges,
calculated as C.R.

and

Pe is percentage expected agreement by chance.

Pe is calculated by finding the proportion of tasks which fall into each category and summing the squares of the proportions. A shortened method of calculating Pe was drawn from Ober et al. (1971). The shortened method involves selecting the two highest proportions and calculating the sum of their squares.

Validating the Scale of Cognitive Demand

Validation of the Scale of Cognitive Demand required establishing both content and construct validity.

The process used in the development of the scale ensured a degree of content validity. A wide range of science materials were sampled to isolate cognitive tasks. Also, existing lists of skills and objectives specific to secondary science instruction were consulted (Gallagher in Schwab, 1970; Schwab, 1970; Tamir, 1972; Cook and Walbesser, 1973; ASEP, 1974a; Henry, 1975; Munro, 1975). During the pilot and subsequent trials the analysts were asked to record tasks that could not be classified according to the Scale of Cognitive Demand.

Eight tertiary science educators from around Australia were used to investigate the construct validity. The validators were supplied with slips of paper, each containing the definition and illustrative examples of a type of task from the scale. All the task types were assigned a random number and the validators were requested to rank them according to cognitive demand.

The construct validation data was analysed in terms of the degree of agreement among the different rankings. The degree of agreement between the eight validators was calculated, in addition to the agreement between the validators and the original scale. The Kendall coefficient of concordance, W , was used to assess the agreement between the sets of rankings. This statistic indicates the level of significance of the agreement, by assessing the divergence of the actual agreement from perfect agreement (Siegel, 1956).

To provide a comparison of the original Scale of Cognitive Demand with the ranks assigned by the validators, the validation data was used to obtain median ranks. From cumulative rank totals, a scale score was derived for each task type, using a computer program, RANKO (Dunn-Rankin and King, 1969). These scale scores indicated the position of each type of task along a consensus scale of increasing cognitive demand, as well as the distances between them.

RESULTS

Justifiable Mismatches

A reading of the literature suggests that there ought to exist a one-to-one correspondence between the objectives, learning tasks, and evaluation. However, examination of the analyses of materials in this study revealed that instances of justifiable mismatch often occur. For example, learning tasks may be structured so that they progress from a low to a higher level of cognitive demand. If the objectives are stated as terminal outcomes, the cognitive demand level of the objectives ought to be higher than that of the learning tasks. Similarly differential emphases on particular objectives, learning experiences or evaluation areas are often reflected by the analyses. The analysis draws the teacher's attention to any areas of mismatch and enables the teacher to diagnose the sources of such mismatches. The instrument provides a quantified basis for evaluation, rather than yielding the evaluation *per se*. The ultimate judgment concerning the extent to which the relation between objectives, learning tasks and evaluation is justifiable remains with the teacher. However, the Scale of Cognitive Demand provides the means for ensuring that such a judgement is an informed one.

Idiosyncratic Use of Materials

It has been long established in the literature that teachers adapt materials to their own situation (Romey, 1973). Discussions with teachers of discrepancies in categorising revealed that teachers often categorised according to their common or intended usage, rather than strictly according to the printed word. This creates great problems with respect to inter-rater reliability. It also highlights the difference between two important types of analyses. For purposes such as the review of materials, it is important that the materials be analysed in terms of the author's intentions. This gives would-be users a clear view of their starting points. For practical usage it is more important for the teacher to analyse according to how the materials will actually be used.

Evaluative Comments from Trial Teachers

The majority of teachers considered that being faced with such a lengthy instrument (24 pages) was a daunting prospect. It was felt that many teachers would not even attempt to use the instrument for this reason. However, there was unanimity that the improved insights were well worth the time spent.

The insights that teachers felt the instrument provided, included: awareness of features that may otherwise be overlooked; a more accurate and objective reflection of the materials (for example, the detailed analysis is often in disagreement with general or initial impressions gained by reading or using the materials); and, revelation of the extent to which student performance on the evaluation instruments accurately represents their mastery of what it was intended they learn.

For one teacher the instrument filled another role:

'The particularly enlightening aspect which using the instrument has provided for me, is the realisation of the variety of demands I could be placing on my students. It has shown me that I neither require the students to cope with a variety of demands, nor give them the opportunity to perform various tasks at a particular level. This variety is now very obvious to me and well within my "grasp". Therefore, I can now work towards providing a range of demands and tasks within my lessons. I expect improved student participation and competence if I succeed.'

Content Validity

Through the development and tryout of the instrument, the following have been analysed: five ASEP units, two JSSP units, six junior secondary Science texts, and one senior text and laboratory manual in each of physics, chemistry and biology. Only one type of task was isolated which could not be classified against the original Scale of Cognitive Demand. This was where students were asked to read and assimilate general background information, particularly in the more 'traditional' texts. This task type has been included in a modified form of the instrument.

Construct Validity

The agreement among the rankings of the validators, and between the validators and the original rankings, gave a value of 0.80 in both cases for W (Kendall's Coefficient of Concordance), with significance exceeding 0.005. The high level of agreement between the validators provided convincing evidence that cognitive demand as defined on the scale is a meaningful construct. The results indicated that this construct was suitable as a basis for distinguishing the types of tasks within the Scale of Cognitive Demand.

Scale scores for each task type were derived from the validation data. These are presented in Table 2. Groups of task types were separated out, based on these distances.

Unitising Reliability

The intra-rater unitising reliability was 0.94. The inter-rater unitising reliability was 0.85 for the teachers who most agreed, and was 0.83 for the teachers who least agreed. In the light of the complexity of the unitising process these are satisfactory reliabilities for a first trial form of an instrument. This suggests that the task types within the Scale of Cognitive Demand were sufficiently distinct to define the unit of analysis.

TABLE 2 - Validation Data - Scale Scores

Scale Score	Original Rank	Original Task Type Number	Task Type	Scale Score	Original Rank	Original Task Type Number	Task Type
51	32	4.8	Extract relevant explicit criteria	1			
52	15, 17	2.4, 2.6	Simple extrapolation; Translate	2			
53	5	1.5	Collect and organise information	3			
54				4			
55				5			
56				6	3	1.3	Observe
57	18	2.7	Summarise	7			
58	20	3.1	Relate	8			
59	35	5.3	Generate relevant criteria	9	2	1.2	Simple Measurement
60				10			
61	28	4.4	Apply a rule or principle	11			
62	23	3.4	Simple hypothesizing	12			
63	40	5.8	Isolate inferences or assumptions	13	6	1.6	Simple Comparison
64				14	1, 4	1.1, 1.4	Recall or memorise specifics; Repeat
65				15	8, 10	1.8, 1.10	Simple Grouping; Simple Recording
66	26	4.2	Internalise a concept	16	9	1.9	Simple Seriation
67				17	11	1.11	Follow a simple set of laboratory instructions
68							
69	38	5.6	Isolate variables	18			
70				19			
71				20	19	3.1	Observe with discrimination
72				21			
73	31	4.7	Extrapolate	22	16	2.5	Plot
74				23			
75				24			
76	24	3.5	Complete an experimental design	25			
77	16, 17	5.4, 5.5	Generalise; Hypothesize	26			
78	39	5.7	Design an experiment or piece of equipment	27			
79				28			
80				29	12	2.1	Recall or memorise procedures, difficult rules or principles
81	25, 33	4.1, 5.1	Understand and apply a model of an abstraction; Construct a representation	30	7	1.7	Simple classification
82				31			
83				32	30	4.6	Classify
84				33			
85				34			
86	41	5.9	Integrate	35	22	3.3	Simple application
87	43	6.2	Assess the impact	36			
88				37	13, 27	2.2, 4.3	Demonstrate use of measuring equipment; Calculate
89				38			
90	42	6.1	Link a model with reality	39			
91				40			
92				41	14	2.3	Understand a direct, physical model
93	34	5.2	Develop an abstract concept	42			
94				43			
95				44			
96	44	6.3	Evaluate	45			
97				46			
98				47			
99				48			
100				49	21	3.2	Develop an operational definition or simple concept
				50	29	4.5	Compare on stated criteria

Categorising Reliability

The intra-rater categorising reliability was 0.78. The inter-rater categorising reliability was 0.46 for the teachers who most agreed, and was 0.36 for the teachers who least agreed. These figures incorporate error due to unitising as well as categorising. Since the categorisation scale consisted of forty-four categories, it could be expected that the reliability of categorisation would not reach the commonly sought level of reliability. The intra-rater reliability measure was satisfactory. However, the results for inter-rater reliability of categorisation indicate a need to clarify the Scale of Cognitive Demand.

In the present study it was considered inappropriate to seek to improve reliability by excluding task types. Decreasing the number of task types may improve reliability but this would be at the expense of content validity. The nature of the Scale of Cognitive Demand is such that all the types of tasks encountered in Secondary Science materials are necessary components. In the modified form of the instrument little-used or apparently redundant task types were subsumed under existing task types.

Modifications to the Scale of Cognitive Demand

Before beginning the re-development of the scale, characteristic elements of the groups were explicated. Since the concept of cognitive demand was also clarified and defined prior to the re-development, it was possible to derive the characteristic group elements from the dimensions of the concept. Reference to these characteristic elements during the modification process ensured that changes were in accordance with the underlying construct of cognitive demand. It also helped to clarify the differences between the groups. In modifying the Scale of Cognitive Demand, the characteristic elements of the groups provided a clarity and focus that had been lacking in the original development. The group characteristics are outlined below, and are summarised in Table 3.

Group 1

Group 1 task types require performing simple operations on data which is readily available to the senses or stored in the memory. Such task types deal with concrete objects or phenomena. They do not demand the generation of new ideas.

Group 2

The types of tasks falling within group 2 rely on a basic understanding. There is little or no generation of new ideas and the data to be operated on are given. The level of abstraction is concrete unless heavily outweighed by other factors.

Group 3

At the level of group 3, the types of tasks demand understanding and/or application, with low level analysis in some instances. A large part of the data is supplied but students are required to generate the final outcomes. Hence, the types of tasks within this group require a limited generation of ideas. They deal with concrete objects, images or familiar phenomena.

Group 4

The types of tasks which fall within group 4 involve application or analysis. They require the generation of ideas from a given data base. The level of abstraction corresponds to a concrete-abstract transition.

TABLE 3 Characteristic Elements of Groups on the Scale*

Group	Dimension of Cognitive Demand			
	Complexity	Openness	Implicitness	Level of Abstraction
1	Simple operations	No generation of new ideas	Data are readily available to the senses	Deals with concrete objects or data stored in the memory
2	Require a basic understanding		Data to be operated on are given	Predominately deals with concrete objects or issues
3	Understanding, application or low level analysis		A large part of the data is given but requires generation of the final outcome	
4	 **	Generation of ideas from a given data base		
5	Analysis and/or synthesis	Generation of ideas which are original for the student	Data are not available in a readily usable form - must be transformed	Abstract
6	Evaluation	Highly generative	Require a view of the entity in question as part of a more extensive whole	Highly abstract

*FOOTNOTE: Although the dimensions of cognitive demand do not lend themselves well to the compartmentalisation of a tabular presentation, this table has been constructed in an attempt to provide a clearer overview of the group characteristics. It should be noted, however, that the dimensions of cognitive demand are not independent but rather, the level of cognitive demand of a task is determined by their interaction.

** The arrows indicate that the characteristic element is intermediate between two more distinct points on the continuum.

Group 5

Group 5 is concerned with types of tasks which require analysis and/or synthesis. Such task types demand the generation of ideas which are original for the student. The data to be operated on are not available in a readily usable form, so that it is necessary to transform the data in accordance with the purposes of the task. Since they deal with the realm of ideas, tasks at this level are abstract.

Group 6

Tasks appropriate to group 6, the highest level of cognitive demand, involve evaluation and are highly generative. They require a view of the entity in question, as being part of a more extensive whole. Such task types correspond to a high level of abstraction.

The data from the application and validation of the Scale of Cognitive Demand exposed specific definitions and examples which lacked clarity and others which were misleading. They also pointed to the need for clearer discrimination between similar categories. In addition, particular types of tasks were identified as being misplaced.

The data obtained from application of the scale provided a large number of specific examples of tasks classified against the types of tasks in the scale. The validation data provided a more theoretically based input.

In comparing teacher feedback with validator feedback it was noted that the validators were totally reliant on the definitions and examples provided to them. The teachers were exposed to a range of examples which often resulted in greater clarity of understanding.

A modified form of the instrument has been prepared and is now ready for the second stage of trialling and validation.

CONCLUSION

The Scale of Cognitive Demand, although of potentially daunting size, proved to be usable by teachers and useful to them. Validation of the Scale confirmed that the cognitive demand construct was meaningful and appropriate for distinguishing between the types of tasks encountered in printed Secondary Science materials. In the light of the data obtained from the trials by teachers, and the validation and reliability procedures, a modified form of the instrument has been prepared. Further research will be undertaken to establish the extent to which the modifications represent real improvements.

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TEACHER TRANSMISSION-INTERPRETATION AND STUDENTS' ATTITUDES TO SCIENCE

P.L. Gardner, E.E. Gray and S.M. Taylor

TRANSMISSION AND INTERPRETATION

Language serves several purposes in the science classroom. For the teacher, language acts as a vehicle for transmitting information, for asking questions to generate feedback, and for directing student behaviour. For the student, language also serves as a vehicle, most frequently for conveying answers to teacher-initiated questions. But in addition, language has an exploratory function: students may use language to investigate ideas, to think things over, to link new ideas to old.

According to Barnes and Shemilt (1974), teachers vary in their beliefs about the relative importance of these different functions. They have conceptualized a continuum, termed transmission-interpretation (T-I) whose two ends represent divergent views about knowledge, learning and teaching.

The transmissive teacher is thought of as one who:

- . regards knowledge as the content of the various academic disciplines
- . values students' performances to the extent that they match the criteria of the disciplines
- . sees his task as the evaluation and correction of the learner's performance
- . considers students as generally uninformed people without much relevant knowledge.

The interpretative teacher, on the other hand:

- . regards knowledge as a personal ability to organize thoughts and actions
- . values students' own interpretations of their observations
- . sees his task as the promotion of discussion through which personal knowledge can be reshaped
- . considers that learners possess relevant knowledge which can be drawn upon.

The research described here accepts T-I as a potentially fruitful dimension, and thus it builds on the work of Barnes and Shemilt. However, the research also differs substantially. For example:

- . it focusses on the verbal behaviour of teachers, and draws upon students' perceptions of that behaviour, rather than teachers' perceptions.

The research was carried out in three phases. Phase 1 was concerned with scale development; Phase 2 investigated concurrent validity; Phase 3 explored the relationship of T-I to student personality characteristics and attitude outcomes.

PHASE 1 : SCALE CONSTRUCTION

A 20-item Likert scale (Table 1) was constructed from a pool of 40 items after a judging phase and a trial on a sample of 362 Year 10 students. These students provided data on 53 teachers.

The trial data were subjected to item analysis, individual factor analysis (on the item scores of individual students) and group mean factor analysis (on the item means for each teacher). Items were then selected by a procedure (McKennell, 1970), which sets out to maximise reliability and minimise test length. The procedure yielded a 20-item scale whose estimated Cronback alpha coefficient was 0.93.

TABLE 1 - Transmission - Interpretation Scale

- 1 (T) In most lessons, my teacher does nearly all the talking.
- 2 (I) Our teacher often helps us to connect new ideas we have learned previously.
- 3 (I) In this class, the teacher allows us to talk about new ideas with other students.
- 4 (T) Our teacher spends a lot of time just following the textbook.
- 5 (T) Our teacher cuts students off in mid-sentence if their answers aren't along the right lines.
- 6 (T) Much of what we learn in this class is irrelevant to the world outside the classroom.
- 7 (I) When we meet a new idea, our teacher explains the evidence and reasoning very carefully.
- 8 (T) Our teacher usually asks the bright students in the class to answer questions because they are more likely to know the right answers.
- 9 (T) Discussion of alternative ways of solving a problem doesn't happen very often in this class.
- 10 (T) Our teacher often says something like "You'd better learn this thoroughly because it's going to be in the exam."
- 11 (I) The teacher allows us to break up into small discussion groups to talk over an interesting idea.
- 12 (T) If a student gives a wrong answer, the teacher often ignores it or says "no" and then asks someone else.
- 13 (T) My teacher likes to get on with the syllabus.
- 14 (I) Our teacher values students' opinions and ideas about a topic.
- 15 (T) My teacher is more interested in checking that we know the right answers, than in our thinking and reasoning.
- 16 (T) In most lessons, our teacher talks and we just sit and listen, or take notes.
- 17 (I) In this class we are given a chance to talk about our experiences if they are related to the lesson topic.
- 18 (I) Our teacher really listens when a student is giving an answer or an opinion.
- 19 (T) Our teacher can get annoyed if someone doesn't know the right answer to a question.
- 20 (I) In this class, students are encouraged to ask the teacher questions.

NOTE

- (T) Transmission item: scored Strongly Agree = 5, Agree = 4, Disagree = 2, Strongly Disagree = 1, Not sure = 3.
- (I) Interpretation item: scored Strongly Agree = 1, Agree = 2, Disagree = 4, Strongly Disagree = 5, Not sure = 3.

PHASE 2 : CONCURRENT VALIDITY

Concurrent validity is concerned with relationships between a variable and other variables which might be expected to be similar to it. Evidence on the concurrent validity of the T-I is available from three independent studies, summarised in Table 2.

Study No. 1 was conducted during the trial of the T-I scale. Students in the sample also completed the Student Perception of Teacher Style (SPOTS) scale (Tuckman, 1970), a 17-item 9-point rating scale measuring teacher direct/indirect (D-I) influence (Flanders, 1970). Although not synonymous, D-I and T-I share some attributes e.g. "teacher stimulates student talk" would be a characteristic of both the indirect and the interpretative teacher. Reliability estimates were available for both the T-I (0.84) and the SPOTS (0.66), and so a correction for attenuation (Thorndike and Hagen, 1969, p.198) could be applied; this upgraded the D-I/T-I correlation from 0.62 to 0.83. The statistical units in this study were the 362 individual students.

In Study No. 2, audio-recordings were made and analyses using a variant of Flanders' Interaction Analysis Categories (Flanders, 1970). For the present study, interpretative teaching was conceptualized as teaching in which there would be a high incidence of (a) teacher stimulation of student talk, (b) indirect influence and (c) sustained student communication, and a low incidence of (d) direct influence. A composite measure of interpretative teaching was formed by standardizing the counts in these four areas of the Flanders matrix, and finding $(a) + (b) + (c) - (d)$. This measure correlated moderately strongly (-0.59) with transmissiveness as measured by class mean scores on the 20-item T-I scale. This is a very important finding, since it demonstrates that the construct can "survive" a shift in both measurement technique (from a high-inference questionnaire to a low-inference analysis of tape recordings) and in the rater (from participating student to independent observer).

The study also employed Rowe's (1974) concept of "wait-time": the interval between the end of a teacher's question and the start of a student's reply. Rowe postulated that increased wait-times would be associated with a less inquisitional and a more conversational classroom climate; students who were not "cut-off" would feel less threatened, and would be more inclined to elaborate their answers.

One might expect that interpretative teachers would display greater wait-times than transmissive teachers. To investigate this, wait-times were obtained from the tape recordings and classified as short (less than 1 second) or long (between 1 and 5 seconds). Wait-times exceeding 5 seconds were regarded as indicative of ineffectual questions, and were ignored. A wait-time rate was then obtained for each teacher by counting the number of long wait-times and dividing by the number of Flanders samples (3-second intervals) in the lesson. The low negative correlation (-0.23) between wait-time rate and class mean T-I indicates a weak tendency for transmissive teachers to allow less time for questions and answers to be processed.

A third aspect of this study was concerned with the cognitive level of questions, using Bloom's (1956) Taxonomy as the basis for the classification. It could be argued that transmissive teachers might emphasize the lower (recall-of-knowledge) levels of the taxonomy, whereas interpretative teachers might ask a relatively greater number of higher level questions. The data, however, do not support this: after categorising questions as low cognitive level (at or below level 1.12 in Bloom's Taxonomy) or high, no correlation was found with class mean T-I measures.

TABLE 2 - Concurrent Validity of the T-I Scale

Study No.	Researcher(s)	Sample (T-I Instrument)	Validating measure(s)	Correlation with T-I
1	Gardner & Taylor (1980)	15 Year 10 classes (N=362) yielding data on 53 teachers in four subjects (T-I: 40-item trial form)	SPOTS (measuring student perceptions of teacher directiveness)	.62
2	Gray (1980)	20 Year 10 science classes in six high schools (N=447) (T-I: 20-item final form)	(a) modified version of FIAC (analysis of audio tapes of lessons, yielding measure of interpretative teaching)	-0.59
			(b) Question-answer wait-time (from the same audio-tapes)	-0.23
			(c) Taxonomic level of teacher questions (same tapes)	.02
3	Gardner (1981)	Technical College apprentices in Refrigeration and Air Conditioning (N=80) taking three subjects: Refrigeration Theory (RT) Electrical Theory (ET) Workshop Practice (WP) (T-I: 12-item shortened version)	Modified version of the <u>Physics Classroom Index</u> , measuring student perceptions of teachers': (a) Achievement pressure (b) Organization (c) Tolerance (d) Pleasure orientation (e) Intellectual ability (f) Compulsiveness (g) Warmth (h) Stimulation	Subjects RT ET WP -.46 -.20 -.19 -.62 -.44 -.54 -.60 -.46 -.61 -.33 -.19 -.31 -.66 -.47 -.51 -.17 +.18 .00 -.70 -.60 -.66 -.54 -.56 -.54

Study No. 3 was an evaluation of a technical college course for refrigeration/air-conditioning apprentices. Students completed an instrument containing nine scales: eight were revised versions of the Physics Classroom Index (Gardner, 1972, 1974), the ninth a shortened version of the T-I. The data were analysed at the individual student level, separately for each of three subjects taken in the course. Teachers who were perceived as interpretative were also regarded as well organized, tolerant, intellectually able, warm and stimulating. T-I would appear to form part of a wider syndrome of teaching behaviour.

PHASE 3 : POSSIBLE INTERACTIONS BETWEEN STUDENT CHARACTERISTICS AND T-I

The value judgement that interpretation is more desirable than transmission underlies much of the work of Barnes. Although his view may be widely shared, it is possible that students may differ in their preferences for interpretative or transmissive teaching. This possibility suggested an aptitude-treatment interaction study; it was hypothesised that students who preferred clearly defined, structured tasks might display greater interest in science when taught by transmissive teachers, while those preferring fewer constraints would show more interest when taught in a more interpretative way. This question was investigated as part of a larger study (Taylor, 1980). Sample. Students (N=420) from 18 Year 10 classes in four state high schools in the Melbourne metropolitan area took part in the study. Girls (N=237) outnumbered boys (N=183), a result of the larger number of boys at technical schools.

Procedures. A questionnaire was assembled with three scales in the following sequence:

Sylbism: The construct "syllabus bound-syllabus free", or "sylbism", (Hudson, 1968; Parlett, 1970) distinguishes students with varying needs for structure in learning tasks. A 20-item scale devised by Josephs and Smithers (1975), was employed. Sample items:

"I would rather follow my own ideas than follow a course",

"I try to keep to the set work and avoid following up interesting sidelines".

Interest. This was measured using a modified Attitude Grid (Duckworth and Entwistle, 1974). To increase the reliability, five items were added to the original five items in the scale. A pilot investigation (on 151 Year 10 students) showed that nine items had high loadings (above .4) on a single factor; the tenth item was excluded from subsequent analyses.

Transmission-Interpretation. The 20-item version of the T-I scale was employed.

Data were gathered during a single visit to each class. Students remained anonymous, but were asked to identify their sex.

The Sylbism scale was scored as a three-point summated rating scale, with a "syllabus-bound" response scoring three points, an ambiguous or no response 2 points and a "syllabus-free" response one point.

Two measures of T-I were derived. The perceptions of individual students, called "individual T-I scores" were obtained simply by summing scores on the 20 items. The consensual or class view of the teacher, called "group T-I scores" was estimated by averaging the individual T-I scores within the class. The Sylbism and Interest scales were completed by all students in the 18 classes. Half of each class, a total of 210 students, provided their perceptions of their science teachers' T-I.

Analysis. The analyses were concerned with three main issues:

- the relationship between T-I and interest in science;
- the relationship between sylbism and interest;
- the possible interaction between sylbism and T-I on interest.

The first two issues were examined at both individual and class levels. Interaction effects were studied by means of a recently developed technique which examines within-class, individual aptitude-outcome regressions, and the relationship between the within class regression coefficients and class mean measures of the treatment variable (Burstein, Linn & Capell, 1978).

RESULTS

The eighteen classes were taught by nine male and nine female science teachers. A one-way analysis of variance on the group T-I scores showed no significant difference between the sexes. Girls had a slightly but not significantly higher mean Sylbims score than boys. Boys obtained a higher mean Interest score than girls in 14 out of the 17 classes in which both sexes were represented. In seven classes there was a statistically significant difference of more than five points in favour of the boys.

Class mean sylbism and interest in science scores are listed in Table 3. When each class is analysed separately, interest generally correlates positively with sylbism and negatively with T-I: students who prefer structure find science more interesting; students who perceive their teacher as transmissive tend to report weaker interest.

TABLE 3 - Mean sylbism and mean interest in science for 18 classes and correlations of each student's interest with sylbism and their perceptions of teacher T-I.

Class	n	Class Mean:		Within Class Correlation of Interest with:	
		Sylbism a	Interest b	Sylbism	Individual T-I
1	22	41.9	19.4	-c	0.4
2	21	41.9	19.4	-	-.3
3	22	42.9	17.2	+	-
4	26	42.1	21.0	+.5	-.8
5	24	44.9	21.8	-	-.3
6	23	42.7	20.5	+	-.4
7	26	40.3	16.7	+	-.7
8	22	44.0	17.5	+.3	-.6
9	22	40.8	16.7	+	+
10	24	41.1	15.0	+	-.6
11	23	44.6	23.0	+.5	-.6
12	23	42.7	16.6	+	-.5
13	28	37.8	14.9	+.5	-
14	26	41.4	21.0	-	-.5
15	18	37.2	15.4	+.4	+
16	25	40.9	17.6	+	+
17	20	43.6	16.2	+	-
18	25	40.2	17.4	+.4	-.5

- a. Potential range of scale: 20 to 60;
 b. Potential range of scale: 9 to 27;
 c. For correlations of magnitude below .3 the direction alone is reported.

Correlations among class means for group T-I, sylbism and interest are reported in Table 4. It appears that classes as well as individuals show more interest when the class is more "syllabus bound" and the teacher more interpretative. However, it is possible that the concept of "syllabus bound" has a different meaning at the class level. For example a class high on sylbism may have group characteristics such as acceptance of traditional schooling and cohesiveness which to some extent influence the attitudes of all its members, the syllabus-free as well as the syllabus-bound.

TABLE 4 - Correlations Between Class Mean Interest in Science, Class Mean Sylbism and Science Teacher Group T-I Scores (N=18).

	Sylbism	Group T-I
Interest	.62	-0.82
Sylbism		-0.35

Interaction effects.

Two matters were investigated:

- . whether the regression lines of interest on sylbism were homogeneous, and
- . whether there was any relationship between the values of the regression coefficients for each class, and the level of that class on the treatment variable (T-I).

If aptitude-treatment interaction is present, the regression slopes will vary from class to class (i.e. they should be non-homogeneous). Furthermore, if the interaction effects are associated with the hypothesised treatment variable, then there should be a significant correlation between the values of the regression coefficient and the measures of that variable.

Although visual inspection of the regression lines (Fig.1) suggests that the regression coefficients vary substantially, a test for homogeneity of regression showed that these differences were not statistically significant. Consequently, there was no need to proceed to the next stage of the analysis.

CONCLUDING DISCUSSION

We believe, with Barnes and Shemilt, that T-I is an important dimension of teacher behaviour. In the present paper, we have attempted to indicate that this construct can be reliably and validly measured, and that it is associated with an important outcome, interest in science. For future research, an investigation of whether T-I is an alterable variable might be profitable. Can teachers deliberately change to a more interpretative style of teaching? If so, would such changes be detected by their students, and would they result in improvements in their attitudes to science?

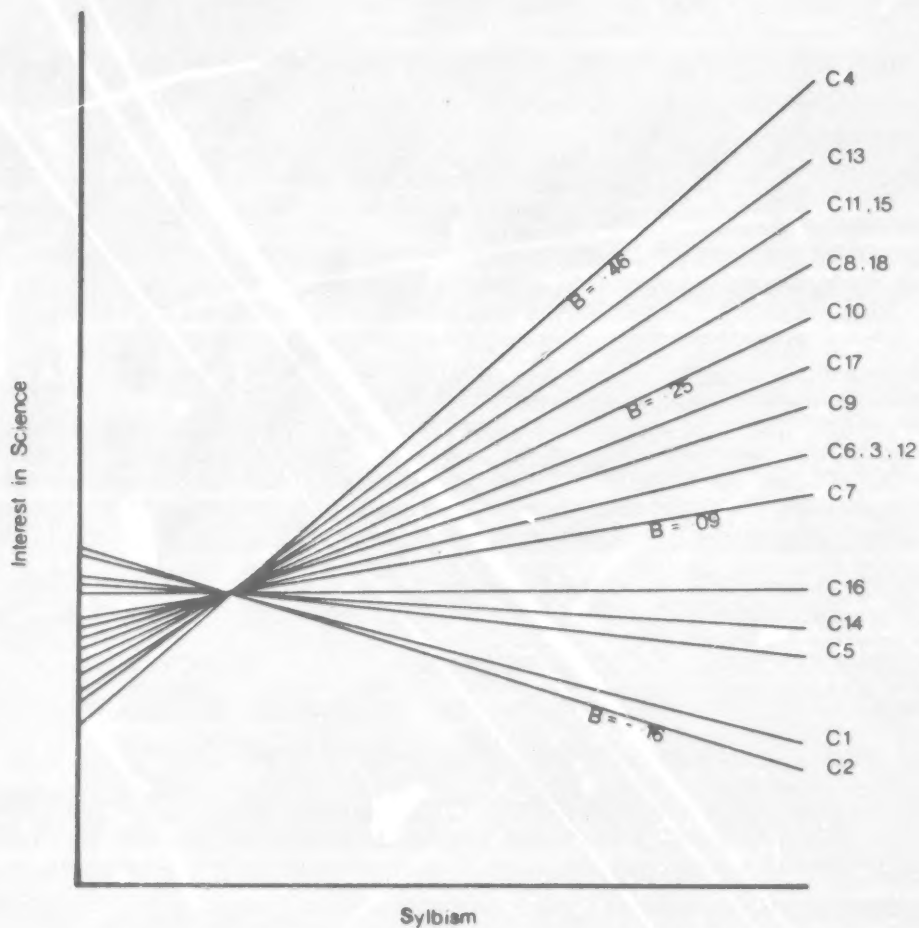


FIGURE 1 - Comparison of unstandardised regression coefficients (B) for the regression of interest in science on student sylbism in 18 classes (C)

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FORMAL SCHOOLING AND THE ATTITUDES OF PAPUA NEW GUINEAN
STUDENTS 1972 - 1980*M.N. Maddock*

This paper reports the results of a study carried out in Papua New Guinea in 1980 into the effects of formal schooling on the attitude towards investigation, control and manipulation of natural phenomena (a "scientific" attitude towards the environment) and on attitude towards traditional religious ideas and practice. The study follows up previous work carried out in Papua New Guinea in 1972 and 1974 by this author, and has been continued in the context of current concern throughout the Third World about the alienating effects of schooling (e.g. Ahmed, 1977).

BACKGROUND

In 1972, the writer developed a measure of the attitude of Papua New Guineans towards investigation, control and manipulation of natural phenomena, the Environmental Phenomena Attitude Scale (EPAS). The technique used was unconventional, the scale consisting of items describing concrete situations, perceived as being feasible in the life of the subjects, with three examples of specific behaviour from which subjects were asked to choose the one perceived as being closest to their own expected behaviour, scored on a three point scale. The instrument was used to investigate the effects of formal schooling, regional (highland-coastal), urban-rural, and male-female differences on the attitude in a sample of grades 8, 9 and 10 high school students and in a sample of village people of about the same age who had experiences only four years or less of formal primary schooling. The scale was administered to one sample of students and villagers by individual, face to face interviews and to a separate, larger sample of students by a group interview technique. Four language versions, namely English, Neo-melanesian Pidgin, Hiri Motu and Enga were used.

The students interviewed were also asked to predict what they thought the village people would answer to the same questions, and were given follow-up, open-ended questions on reasons for answers given. The predictions for villager responses were scored in a similar manner to their own answers. More details can be found in Maddock (1973A, 1973B, 1974A, 1974B, 1975A, 1975B).

In 1974, a replication was carried out with an extension in which the sample was expanded to include people ranging from those possessing no formal schooling through all levels of primary and secondary schooling to those with tertiary education. The dimensions were broadened to include the New Guinea islands and to examine the effect of differing levels of mission schooling in the subjects' formal education. Three further language versions were used (Kua Nua, Toaripi and Pure Motu). Reports on this study can be found in Maddock (1977A, 1977B, 1980). Randell (1977) used the same scale production technique to develop a pencil and paper instrument to measure traditional religious attitudes (TRAS) and used it on a sample of grade 8 students using the new Religious Studies Curriculum in 1973.

THE 1980 STUDY

In 1980, the writer carried out a follow-up study to further evaluate both EPAS and TRAS and to assess the status of the attitudes after a substantial period during which attempts had been made to make the curriculum more appropriate for Papua New Guineans.

The two instruments, this time administered as paper and pencil tests in English only, were given to grade 8 and grade 10 high school students in the Central, Eastern Highlands and Simbu provinces, closely similar to the 1972 and the 1974 samples. Three government and four church agency schools were used to obtain 971 students. Each respondent was asked to record two answers to each question: their own response and their prediction for the response from a person who had not been to school. This paper reports analyses carried out to date which enable direct comparisons to be made with the 1972 and 1974 projects with EPAS and with the Randell (1977) study.

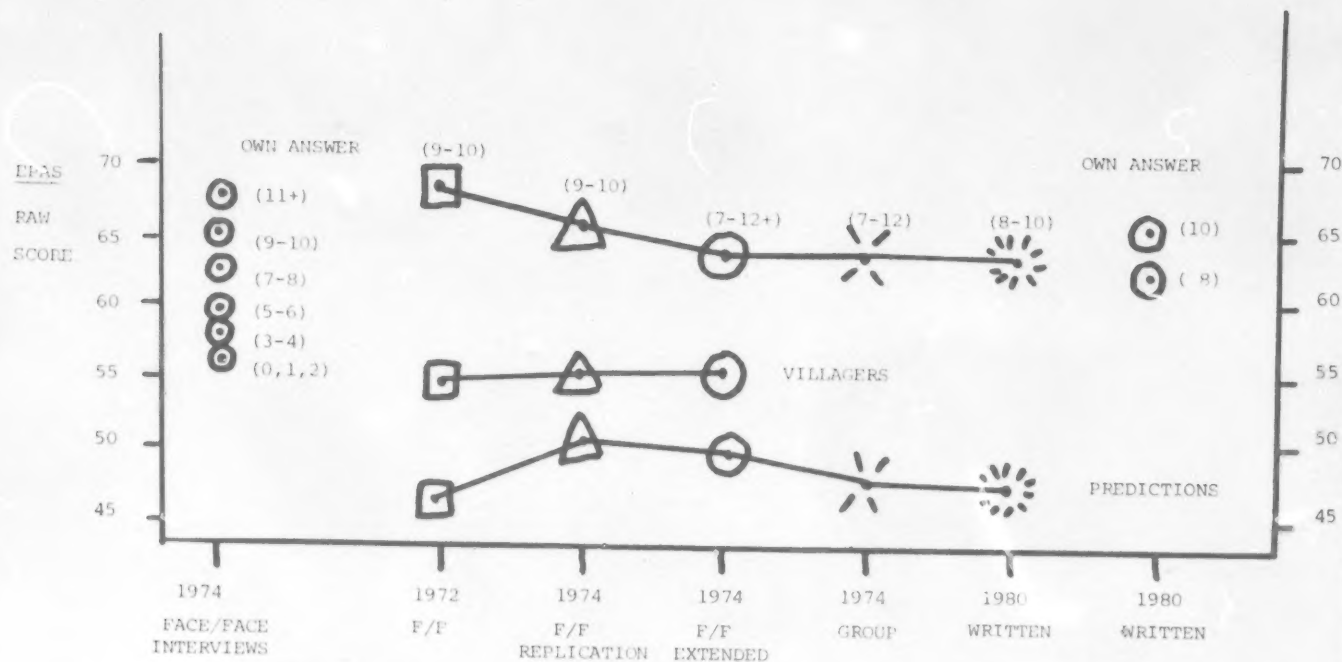
RESULTS OF REALIBILITY ANALYSES

Instrument Reliability EPAS

EPAS was designed for use with a population of Papua New Guineans ranging from people with no formal schooling at all through to people with secondary or higher education. In the 1972 and 1974 studies, coefficient alpha reliability for this total sample ranged from 0.71 to 0.89. The high school students represent an upper, restricted range sample, for which a lower level of reliability could be expected (Nunnally, 1969). The 1980 study reflected the consistent level of reliability found in the 1972 and 1974 projects, with the "restricted range" student sample producing an alpha of 0.66 for the "own answer" responses and 0.70 for the predictions, consistent with Nunnally's (1969) criterion level for adequate reliability for group comparisons in research studies and similar to the pattern of the previous studies where the alphas ranged from 0.50 to 0.65 for students. The 1980 alpha for TRAS (grades 8 and 10) of 0.90 was almost identical with the Randell (1977) figure of 0.91, obtained on Grade 8.

EPAS, Own-Answers Compared with Predictions

The overall pattern of results obtained in the 1980 study was highly consistent with those obtained in both the 1972 and 1974 projects; as can be seen from Figure 1. The possible score range was from 26 to 78. The difference of 16.4 scale points between the "own-answer" and prediction means in 1980 is of the same order as that found in both 1972 and 1974, the related t ratio (42.1, df 923) being highly significant at the 0.001 level, with a point biserial correlation of 0.81 (Cohen, 1969, p. 102) indicating that about 66 percent of variance is associated with membership of the "own answer" - prediction categories. Further consistency across the studies is shown by the close similarity of means for the different grades (65.6 for Grades 9-10 in 1974 as compared with 65.7 for Grade 10 in 1980 and 62.9 for grades 7-8 in 1974 as compared with 62.2 for grade 8 in 1980). The consistent gap across the studies between the "own-answer" and prediction means can be interpreted as a measure of a strong socially significant degree of "attitudinal alienation" from the norms of the village community developed by students.



NOTE: Figures in parenthesis represent maximum grade level achieved by subjects.

FIGURE 1. Plot of means for studies using the Environmental Phenomena Attitude Scale (EPAS) 1972-1980.

Educational, Regional and School-type Effects

Each of the "own-answers" and predictions of villager responses for both EPAS and TRAS were subjected to a 2 x 2 x 3 analysis of variance on level of formal schooling, regional and type of school background (all government schooling, mixed government-church agency or all church-agency) dimensions. The significant results obtained on these analyses are summarized in Table 1.

TABLE 1 - ANOVAS Significant Results

ENVIRONMENTAL PHENOMENA ATTITUDE SCALE (EPAS)					
DESIGN	RESPONSE	SOURCE	F	% VARIANCE	P
Region/Grade/School Type	Own	Region	11.2(¹ / ₉₃₀)	1.08	0.000
		Grade	101.8(¹ / ₉₃₀)	9.61	0.000
		R x ST	3.3(² / ₉₃₀)	0.05	0.037
		R x G x ST	4.3(² / ₉₃₀)	0.06	0.014
PREDICTIONS		Region	10.5(¹ / ₉₂₄)	1.02	0.001
		Grade	14.0(¹ / ₉₂₄)	1.39	0.000
TRADITIONAL RELIGIOUS ATTITUDE SCALE (TRAS)					
Own		Region	43.5(¹ / ₉₅₇)	4.41	0.000
		Grade	51.7(¹ / ₉₅₇)	4.84	0.000
		School type	8.3(² / ₉₅₇)	1.50	0.003
PREDICTIONS		R x G x ST	4.19(² / ₉₃₆)	0.07	0.020

ANOVAS EPAS Own Answers

As in the 1972 and 1974 studies, level of formal education was the major factor affecting scores on the attitude scale. The grade 10 mean was significantly higher ($F_{101.8}$, $p < 0.001$) than the grade 8 mean by 3.4 points (0.6 of a standard deviation), about 10 percent of the variance, calculated from epsilon (Cohen, 1965, p. 103), being associated with membership of grade 8 or grade 10.

There was a significant regional effect, with the highland mean 1.3 scale points (0.2 of a standard deviation) higher than the coastal mean and an F value of 11.18 (df 1/930, $p < 0.001$), compatible with, but of smaller dimension than a similar regional difference found in 1974. However, only about 1 percent of variance was associated with regional membership.

As in the 1974 study, there was no school type effect, the means for students with only government school, mixed government school and church agency, and entirely church agency backgrounds being 63.1, 64.2 and 63.8 respectively. Statistically significant region x school type and grade x region x school type interaction effects were found (see Table 1 and the own-answer plots at the top of Figure 2), although the percentage of variance explained is less than 1 percent in both cases.

ANOVA EPAS Predictions

Small, but significant regional and grade level effects were found for EPAS predictions. The highland mean of 46.8 was 1 scale point (0.2 of a standard deviation) lower than the coastal mean of 47.8, while the grade 3 mean of 48.9 was 1.8 (0.3 of a standard deviation) lower than the grade 10 mean, but only about 1 percent of variance was associated with regional or grade difference as far as the predictions are concerned. There were no significant interaction effects.

Unlike in 1974, where students educated in church agency schools were significantly more negative in their predictions for response by uneducated village people, there was no school type effect in the 1980 study, with the mean for student with all government school background being 47.1, for mixed background 47.6 and for all church agency background 47.3.

Attitudinal alienation

As mentioned previously, in each of the 1972, 1974 and 1980 studies a large difference was found between the means for the students' own answers and for their predictions for responses by village people. This can be attributed to the extent of "attitudinal alienation" with respect to the particular attitude measured by EPAS, the level of formal schooling attained having been shown in all three studies to be the major factor involved.

As can be seen from Figure 2, the order of magnitude of the alienation has not changed during the period covered by the studies, although there are minor differences between students with different school-type background in the 1974 and 1980 studies. When the 1980 results are compared with the 1974 face to face interview results, as shown in Figure 3, it can be seen that the level of alienation in the 1980 study is somewhat greater in students of government school background than it was in 1974, whereas there has been little change in the level of students with church-agency background.

TRAS Own Answers Compared with Predictions

In the Randell (1977) study no predictions for villagers' responses were asked for and no study was carried out with village people. In this 1980 study, predictions were required and an attitudinal alienation gap of an even stronger degree of magnitude than found for EPAS was noted. The difference between the own answer mean (80.5) and the mean for the predictions (46.8), on a raw score range 90-30, was 33.7 scale points, compared with the standard deviation of 8.7 for the own answer scores and 11.0 for the predictions. The correlated t ratio was 61.3 (df 935. $p < 0.001$) and the point biserial correlation was 0.89, representing about 80 percent of variance explained by membership of the scores in the two categories.

The mean for the grade 8 (own answer) sample in 1980 was 78.7, compared with the value of 79.7 obtained by Randell (1977) in 1977.

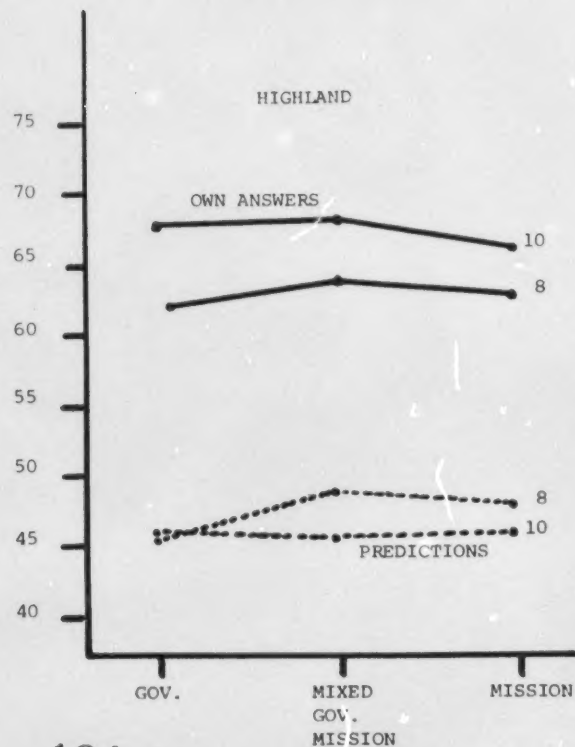
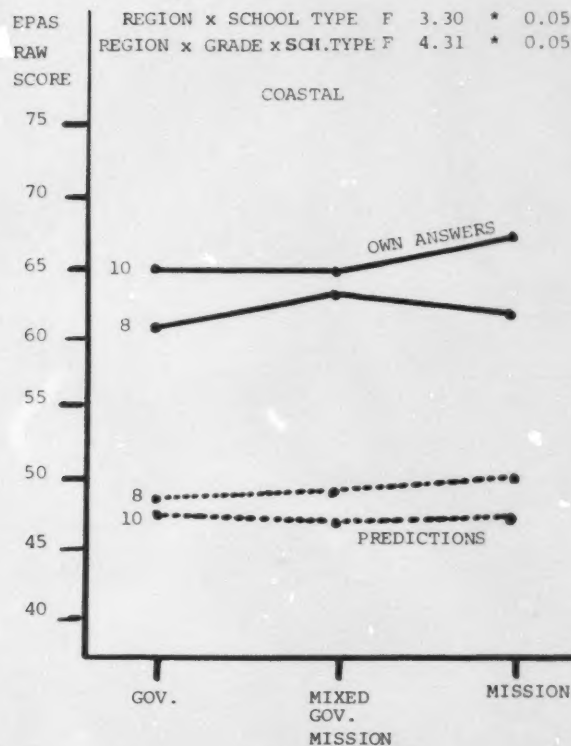
FIGURE 2 - Plot of means, region : grade level x type of school background, for ANOVA, EPAS (own answers and predictions), 1980

EFFECTS - OWN ANSWER

REGION	F	11.18	*	.001
GRADE	F	101.81	*	.001

EFFECTS - PREDICTIONS

REGION	F	10.49	*	.001
GRADE	F	13.97	*	.001



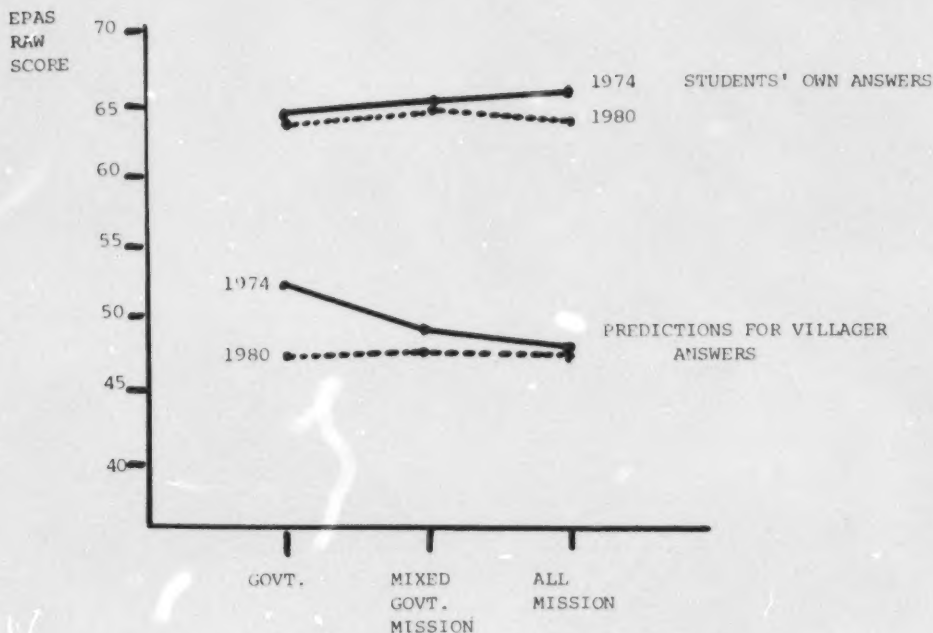


FIGURE 3 - Plot of means showing comparison of EPAS (Own Answers and Predictions) 1974 and 1980 for students with all government school, mixed government and church agency school and all church agency school background.

ANOVA TRAS Own Answers

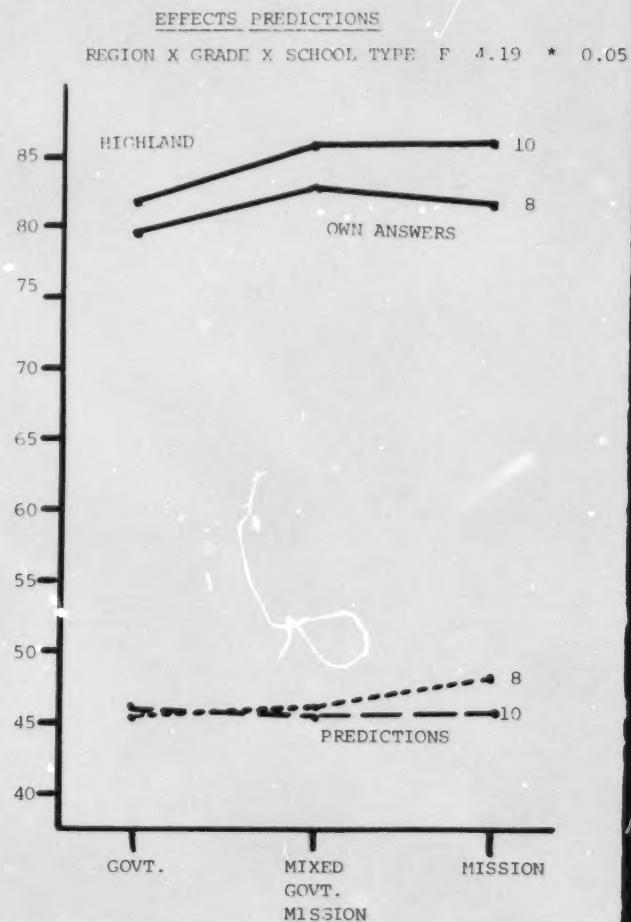
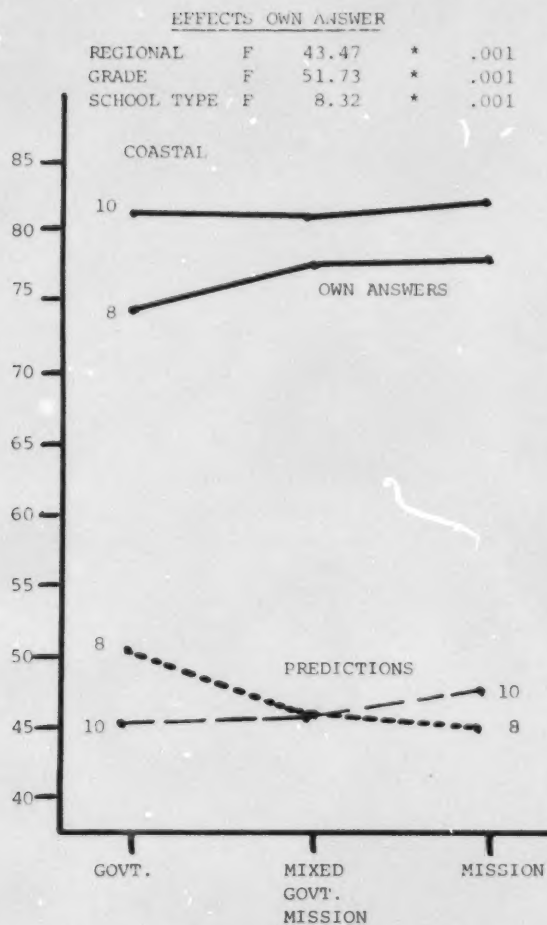
As with EPAS, significant regional and grade level effects were found, all at 0.001 level, but in this case, a significant school-type effect also occurred. No interaction effects were found.

As in the case of EPAS, the highland mean (82.6) was higher than the coastal mean (78.5), the difference of 4.1 scale points representing about 0.5 of a standard deviation, about 4 percent of variance being related to regional membership, a significantly stronger regional effect than that found for EPAS.

The grade 10 mean of 82.6 was 3.9 scale points, (0.4 of a standard deviation) higher than the grade 8 mean of 78.7, representing about 4 percent of variance associated with grade level membership, an effect of somewhat less strength than that found with EPAS.

In the case of the school-type effect, the mean for students with all government school background was 78.5, with mixed government-church agency background 81.1 and with only church agency background 82.6, a progressive increase with increasing church agency influence. Applying the Scheffé technique (Kerlinger and Pedhazur, 1973, p. 128-131), the difference between the mixed mean and the government mean of 2.6 is greater than the calculated S of 1.36, and thus significant at the 0.01 level, but the difference between exclusive and mixed church agency influence of 0.9 ($S = 1.38$ for $p > 0.01$) is not significant.

FIGURE 4 - Plot of means, region x grade level x type of school background, for ANOVA, TRAS (own answers and predictions), 1980



ANOVA TRAS Predictions

In the case of the predictions by students for the responses of uneducated village people, the only significant effect found was the three way interaction between region, grade and school type, with an F of 4.19, significant at the 0.05 level. The effect is of small magnitude, with less than 1 percent of variance associated with the interaction effect. The effect can be seen in the plot of means in Figure 4, where the highland mixed and church agency grade 8 means are higher than the grade 10 means, whereas in the coastal sample, the government grade 8 mean is higher, the mixed means are about the same, but the church agency grade 10 mean is higher.

The differences of -2.0 and -0.4 in the case of the highlands mission, and mixed groups and of +2.0 in the case of the coastal mission, or church agency group, represent differences of 0.2 of a standard deviation or less, but the coastal government difference of 5.2 in favour of grade 8 represents almost 0.5 of a standard deviation. Based on Scheffe test calculations, the first 3 differences are not significant, but the latter is significant at the 0.05 level, the Scheffe S being 2.65 for this contrast.

Attitudinal alienation

It can be seen from Figures 2, 3 and 4 that the pattern of attitudinal alienation with respect to the Traditional Religious Attitude Scale is very similar to that displayed in the case of the Environmental Phenomena Attitude Scale, although the gap in TRAS is of a much larger dimension in proportion to the scale standard deviation. The level of alienation is stronger in the case of highland subjects, and as was found in the case of EPAS in 1974, the gap is significantly greater for students with church agency school backgrounds.

DISCUSSION OF RESULTS

The results of the studies with EPAS and TRAS over the period 1972-1980 have implications for both methodology in attitude research and for curriculum development in Papua New Guinea.

The results of the 1980 study add to evidence already accumulated in Papua New Guinea (Maddock 1973B, 1978, 1979, Randell 1977) in support of the usefulness of the attitude scale construction technique of basing items on statements of a concrete situation with choices of specific concrete behaviour, as an alternative to more generally used techniques such as Likert scaling or semantic differential scaling. The results of the studies suggest also that face to face interviewing, group interviewing and pencil and paper techniques are equally appropriate techniques, producing comparable results in the Papua New Guinea situation.

Although there have been changes in curriculum emphasis over the period 1972-80, from that with an Australian orientation towards content and approach considered more appropriate to Papua New Guinea conditions, with more recognition of local culture, there has been virtually no change in the effect of formal schooling on attitude towards investigation, control and manipulation of natural phenomena. The strong degree of attitudinal alienation which existed between high school students and minimally educated village people in 1972 still exists in 1980. It is evident that formal education also results in a similar level of alienation as far as traditional religious attitudes are concerned. The gap between the attitude of the students and their perception of the attitude of village people is of considerable magnitude and social significance.

In both scales, the grade level of the subjects was a substantial factor affecting the "own answer" scores, with the grade 10 means being higher than the grade 8 means. For EPAS, this result is consistent with results of the 1972 and 1974 studies.

For EPAS, in the case of the predictions, which represent the perception by students of the attitude held by minimally educated village people, the grade 10 mean was lower than the grade 8 mean. In the case of this attitude, the more formal schooling a person has received, the greater is the alienation gap, due to the development of a more positive attitude, at the same time as a more negative perception of villager attitudes, by the students, as can be clearly seen in Figure 3.

In the 1974 study with EPAS, there was no school-type effect for "own answer" responses for the face to face interviews, and a small but significant effect for the group interviews, with church agency background students in the latter case having slightly more positive attitudes. In both the face to face and the group interviews there was a significant school type effect for the predictions, the more negative predictions being from those with church agency backgrounds. The resultant of this effect in both cases was that attitudinal alienation increased with increasing church-agency background.

In the 1980 study, there was no school-type effect with either the own-answer responses or the predictions, and thus there is no difference in the alienation gap between the students' own attitudes and their perception of villager attitudes across the different types of school background. When compared with the 1974 studies it can be seen that this can largely be attributed to an increase in the negative direction for the predictions of students with government school background (see Figure 3), over the results found in 1974.

However, in the case of the Traditional Religious Attitude Scale, this alienation gap is greater for mission educated students than for government educated students, complicated somewhat by the interaction effects (see Figure 4) and is also greater in the case of the highland students than in the case of the coastal students. The school-type effect can be more clearly seen in the plot of means in Figure 5.

In the report to the Education Department of Papua New Guinea on the 1974 study (Maddock, 1977B), attention was drawn to the implications of the attitudinal alienation developed in attitude to investigation, control and manipulation of natural phenomena by formal schooling:

educationists in Papua New Guinea need to consider whether such a gap is an outcome which can be socially tolerated, and if not, what curriculum or organisational changes in the educational system need to be instituted

One certainty is that a major degree of cultural alienation between the educated people, who are planning and instituting development programmes for the country, and the general level of the population, who have to participate in and are supposed to benefit from such programmes, can introduce social tensions which can materially affect their programme's success.

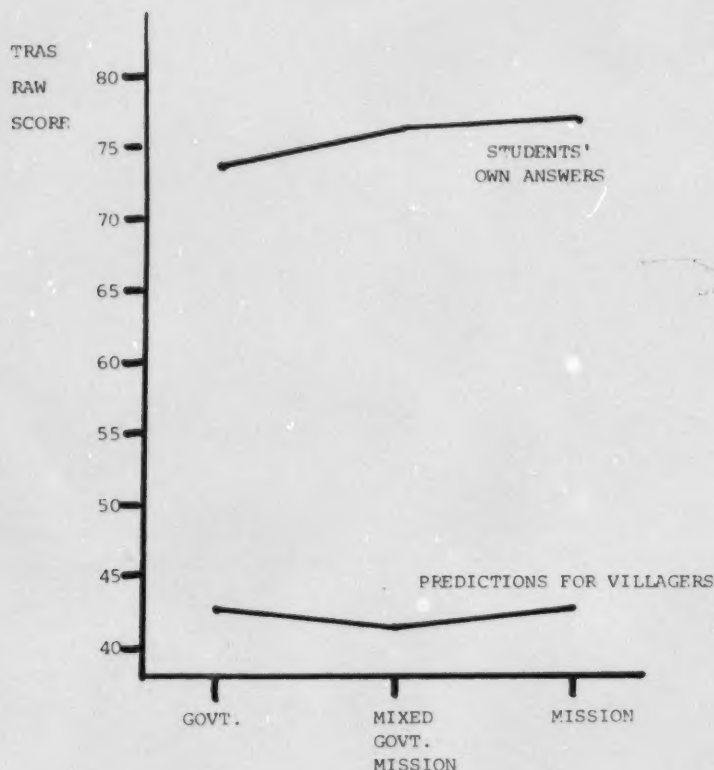


FIGURE 5. Plot of means from ANOVA of TRAS, 1980, showing attitudinal alienation gap between the "own answers" and their predictions for responses of minimally educated village people by students with all government school, mixed government and church-agency school and all church-agency school background.

The "generation gap" is not a new concept where formal schooling is concerned in any country. The Papua New Guinea studies suggest that the "generation gap", manifested in the results by differences between the attitudes of educated people and uneducated village people, as in the 1972 and 1974 studies, and by the very negative perceptions by educated people of attitudes held by minimally educated village people in all of the studies, in the case of both "scientific" attitude to natural phenomena and of traditional religious attitudes, is one of serious dimension. This gap has continued to survive over an 8 year period, despite attempts to change curriculum emphasis towards more Papua New Guinean cultural relevance. The open-ended follow-up interviews conducted in both 1972 and 1974 strongly suggest that in the case of EPAS, school science was an important contributor to developing the gap.

These studies give graphic quantitative measures of the extent of the alienation, which has been qualitatively recognized in the past, for example by Draper (1974, p. 12):

After years in an urban educational environment, the younger member tends to regard the villager as absurdly primitive and ignorant; the elder in turn feel so ill at ease with the young sophisticate that they in turn maintain their sense of dignity by barring him from village debates and councils, suggesting that he has sold out to the European and forsaken his heritage.

The problem has been recognized by education authorities in Papua New Guinea, as indicated in the Papua New Guinea Education Plan (1975):

A school which imparts inert ideas and turns a child against his culture is simply an unsatisfactory school.

The Secondary Schools Community Extension Project (SSCEP), (Stanton, 1977), represents one of the measures being attempted to counteract the problem.

However, the fact is that there has been no systematic attempt to evaluate the relationship between curricular, pedagogical and socio-cultural factors in the development of desired and undesired attitudes in the products of the formal education system in Papua New Guinea, or elsewhere in the Third World, where similar problems exist. More work is still to be carried out on the data collected in the 1980 study, to investigate the relationship between scores on the two attitude scales (EPAS and TRAS) and between the two scales and factors such as achievement in school subjects, and church attendance, in the hope of throwing some light on the problem. There is also a need for further concerted and systematic long-term studies.

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WHAT DO THEY SAY THEY WANT? YEAR 7 STUDENTS' PREFERENCES IN SCIENCE

C.J. Dawson and N. Bennett

Student interest in science may be investigated at various levels of specificity from an interest in the subject as a whole, through interest in defined but broad areas of science and to interest in specific topics. Little work has been reported at this last level, yet such information can be of particular advantage to those curriculum planners and teachers who see knowledge of student interest as a source for input into curriculum making decisions.

Investigations of interest in specific science topics have often focussed on identifying the science related activities in which students engage in their free time (Foster, 1967; Cooley and Reed, 1971; Skinner and Barcinowski, 1973). An alternative approach (Clarke, 1972; Sullivan, 1979) has identified the science topics students say they would like to study.

In Sullivan's (1979) report, the results of a major U.S. study, Survey of School Attitudes, were used to illuminate the specific science interests of grade 1 - 8 students, the students being asked to indicate whether or not they would like to study some fifteen specified science topics.

In order to obtain useful information for the teacher or curriculum planner concerned with student specific interests this methodology appears to be very appropriate, however Sullivan's report shows two major limitations: (1) the minimal number of items; (2) the wording in which the specific science topics were framed. Topics such as "the sun and planets", "how the heart works" and "insects" were prefaced by introductory phrasing such as "learning about" and "working with", yet the factor analytical work of Skinner and Barcinowski (1973) makes it quite evident that the degree of anticipated practical involvement when studying a topic may influence its appeal to students. There may be quite different interest expressed in two supposedly equivalent statements such as "learning about insects" and "working with insects". Thus refinement of the Survey of School Attitudes instrument necessitated firstly an increase in the number of items and secondly a phraseology more neutral with respect to the degree of active participation inherent in the study of each topic.

Whilst knowledge of student interest in specific science topics can be of value to the planner of the curriculum, so also can a knowledge of the appeal of different teaching methodologies to the students concerned. Few reports have appeared in this area though Sumner and Wilson (1972) noted that lower high school students in South Australia say they prefer group work to individual work and both boys and girls enjoy finding out about things and doing experiments and dislike being told exactly what to do by the teacher.

The focus in the discussion so far has been primarily on students' specific interests, nevertheless it is evident that such data lends itself to investigations of the grouping of interests, through factor analytical studies, and the differences in interest of different groups. And in fact previous studies have revealed important grouping of interests (Skinner and Barcinowski, 1973) and group differences relating to age, sex and geographical location (Foster, 1967; Sumner and Wilson, 1972; Clarke, 1972; Sullivan 1979).

PROCEDURE

The instrument

The instrument consisted of two parts. Part I, the Science Topics inventory, asked students to indicate how much they would like to learn about seventy seven specific science topics. Students responded on a 5 point scale ranging from "I would very much like to learn about this topic" to "I would definitely not like to learn about this topic": also included was a "I don't understand what is meant" alternative.

The items were chosen from topics included in upper primary science books and resource material produced in Australia, the U.K. and the U.S. and were those commonly found in such texts. Topics were selected to give approximately equal weighting to the broad science areas which were emphasised in the texts and included items in areas of human biology, general biology, earth sciences/ astronomy and the physical sciences. (The approximately equal number of items in these areas over-emphasised the relative amount of human biology in the texts). In addition several items referring specifically to practical activities were included.

Following two separate trials and student and teacher comment the final format was an instrument consisting of 77 items with 19 items from the area of the physical sciences, 17 from human biology, 18 from general biology, 19 from earth science/astronomy and 4 practical items.

The associated Science Activities inventory listed seventeen methodologies which might be selected by teachers in the teaching of science. Students were asked to indicate, again on a 5 point scale, how much they would like to learn science by each method.

Following the completion of each inventory students were invited to add other science topics or activities in which they were interested.

Sample

753 students, 400 boys and 353 girls, in year 7 of South Australian government schools completed the instrument. Twenty four schools were selected randomly from sublists of metropolitan primary, country primary and country area schools. Each school so selected was approached to participate in the study and most responded in the affirmative, schools not participating were replaced by reserves. The relative number of students in the three types of school closely matched the overall distribution of year 7 students in such schools. All year 7 students present in each school completed the instrument.

Method of Scoring

Each response was scored 5-1, with "don't understand", being separately coded. A mean value was calculated on each item for the total group and for the various subgroups boys and girls, and city and country dwellers. All statistical transformations were undertaken using SPSS programmes (Nie et al., 1975).

ALL STUDENTS

1. Poisonous animals (4.12)*
of Australia
2. The growth of a baby inside its
mother.
3. Animals which are rare or almost extinct
4. Simple expts. in chemistry.
5. Crystals
6. {Heart attacks & how they are caused
7. {How to dissect dead animals
8. {Smoking and health
9. Earthquakes
10. Fossils (3.76)
11. The inside of the earth
12. How children change as they get
older.
13. How to use science instruments
14. How animals behave toward each other
15. Our brain and nerves
16. Animals that live in the sea
17. How caves are formed
18. Heating, burning and fires
19. {How we use our muscles & bones to move
20. {Why children tend to be like their
parents. (3.74)

BOYS

- Poisonous animals (6)** (4.21)*
of Australia
- Simple expts. in chemistry (14)
- Earthquakes (30)
{Rockets (77)
{How to dissect (22)
- Electricity, batteries etc. (72)
How to use science instruments (38)
The inside of the earth (28)
- Dinosaurs (61)
Animals which are rare (7) (3.91)
Volcanoes (53)
Fossils (12)
- Man in space (65)
{Heating, burning (36)
{Crystals (9)
How caves are formed (32)
The moon (50)
Animals that live in the sea (24)
{How to use a microscope (55) (3.68)
{Using energy (41)

GIRLS

- The growth of a baby inside its
mother. (26)** (4.28)*
- How children change as they get
older (44)
- Heart attacks (29)
Smoking and health (26)
Why children tend to be like their
parents (55)
Poisonous animals of Australia (1)
Animals which are rare (10)
How animals behave toward each
other (36)
Crystals (14)
Our brain and nerves (33) (3.75)
Our teeth etc. (58)
{How people are different from each
{other (60)
{Fossils (12)
Simple expts. in chemistry (2)
Common birds (42)
The heart, blood vessels (39)
Different foods we eat (74)
Germs and diseases (64)
Digestion of food (67)
Common wild flowers (77) (3.55)

* mean value for item

** position of same item for other sex

TABLE 1 - The most popular 20 science topics for all students, boys and girls
(Some topic headings are abbreviated)

RESULTS

Table 1 shows firstly the 20 most popular topics (in order of item mean) for all students. This list masks the different rank orders of various groups, in particular the very great differences between boys and girls where only 5 items appear in the "top 20" of the two lists. The "top 20" for boys and girls separately are also displayed in Table 1.

Inspection of these "tops 20s" reveals that girls express more interest in the human biology topics, and 12 of their "top 20" are from this area. On the other hand boys show greater interest in topics from the earth science/astronomy (10 items) and physical science (3 items) areas, and none of their "top 20" is from human biology. The mean values on the five sub-scales and the t-test of significance shown in Table 2 illustrate the strength of these differences.

TABLE 2 - Mean scores and significant differences in sub-scales constructed from all items in science topics inventory

	Physical Science Scale (19 items)	Earth Science Scale (19 items)	General Biology Scale (13 items)	Human Biology Scale (17 items)	Practical Scale (4 items)
Boys (Mean score)	61.98	69.95	55.70	53.74	15.89
Girls (Mean score)	53.12	56.50	60.37	63.30	13.20
T-test of significance	$p < .001$	$p < .001$	$p < .001$	$p < .001$	$p < .001$

Table 3 shows the rank order of science activities for all students, boys and girls. Apart from a single item, "make your science workbook colourful and attractive", the difference between the sexes were not major and will not be discussed here.

Principal component analysis of the Science Topics inventory produced fourteen components with eigenvalues greater than 1, however application of the scree criterion (Cattell, 1966) resulted in 8 of these, accounting for 54.5% of the variance, being extracted. Following rotation according to the varimax criterion the first three factors were named general biology, earth science/astronomy and human biology factors, for the items loading significantly on these were virtually identical with those originally inserted into the inventory. Factors 4 and 5 were not so clearly defined but for the most part factor 4 consisted of "physics" items and factor 5 "chemistry" items and together they included virtually all of the physical science items together with the practical items "how to use some instruments scientists use" (factor 4) and "simple experiments in Chemistry" (factor 5). The other factors were not interpreted.

Separate analyses of the boys' and girls' data revealed generally similar patterns though the first five factors were not exactly the same order and for girls a single "physical science" factor extracted as the second factor had significant loadings from all the physical science items.

Separate scales designed to reliably assess students' interests in the four areas of science considered here were developed from the factor analysis data. Items loading above 0.30 on each major factor were grouped together as separate scales and the individual item - rest of scale correlations and the internal consistency of each scale were used to eliminate items and monitor

TABLE 3 - Science methodologies in order of preference for all students

Separate Mean Values and rank order of preference for each item for boys and girls

METHODOLOGY	BOYS			GIRLS	
	MEAN	MEAN	RANK ORDER	MEAN	RANK ORDER
1. Go on visits to zoos parks etc.	4.40	4.30	2	4.51	1
2. Do your own experiments	4.34	4.47	1	4.19	2
3. Watch films about science topics	3.97	4.01	4	3.72	4
4. Make models about science topics	3.86	4.11	3	3.57	6
5. Watch slides or filmstrips	3.79	3.91	5	3.65	5
6. Watch T.V. programmes in science	3.65	3.81	6	3.47	7
7. Make copies of science pictures and photographs	3.50	3.58	7	3.41	9
8. Watch the teacher doing experiments	3.46	3.48	8	3.43	8
9. Make your science workbook attractive and colourful	3.43	3.03	12	3.88	3
10. Do a project about a science topic	3.10	3.05	9	3.16	11
11. Discuss science topics with other students	3.04	2.98	13	3.20	10
12. Listen to visitors talk about science	2.98	3.04	10	2.90	12
13. Listen to radio programmes about science	2.88	3.04	10	2.71	15
14. Find out answers to science questions	2.79	2.85	15	2.72	14
15. Read books on science	2.70	2.89	14	2.50	16
16. Copy notes about science from the blackboard	2.55	2.30	17	2.80	13
17. Listen to the teacher about science topics	2.52	2.58	16	2.45	17

the homogeneity of each scale. The result was four scales, each with an internal consistency greater than 0.9, but of lengths varying from 12 to 20 items. The mean scores of boys and girls, the internal consistency of each scale and the abbreviated results of the t-test of significance between boy and girl means are shown in Table 4. Analysis of variance showed that the variance accounted for by sex-group membership was 30% on the physical science scale, 22% on earth science, 8% on human biology and 5% on general biology.

TABLE 4 - Mean Scores, Significant Differences and Internal Consistencies of Scales Derived from Factor Loadings

	Physical Science (12 items)	Earth Science (13 items)	General Biology (20 items)	Human Biology (13 items)
Boys (mean scores)	43.13	49.34	62.22	42.28
Girls (mean scores)	31.78	37.93	67.15	48.54
T-test of Significance	$p < .001$	$p < .001$	$p < .001$	$p < .001$
Internal consistency of scale α	.906	.924	.923	.905
ANOVA - explained variance	30.3%	22.2%	4.9%	8.4%

Principal component analysis of the Science Activities inventory followed by varimax rotation extracted four factors accounting for 55.4% of the variance. Factor 1 included methodologies illustrative of a conservative teaching approach with a considerable amount of teacher direction. Factor 2 was an audiovisual factor and included only the four items of this nature in the inventory. Factor 3 incorporated methodologies where the student might expect to have a certain degree of independence, such as in doing experiments and making models and factor 4 was a unique factor with only "watch teacher doing experiments" loading on it.

Boys' and girls' data factorised separately showed similar patterns, though only the first three factors were extracted from boys' data. From the girls' data a further two unique factors "watch teacher doing experiments" and "make workbook colourful and attractive" were extracted. What did appear evident however is that some methodologies are seen somewhat differently by boys and girls, thus "discuss science topics" is clearly an independent methodology for girls but primarily a restrictive methodology for boys: in addition some methodologies appear to have both a dependent and an independent component (e.g. do a project, find answers to science questions) as they loaded significantly on both factors.

DISCUSSION

An original aim of this study was to identify specific science topics which year 7 students say they would like to study and the methods by which they would prefer to study them, in order to provide useful information to teachers. The timing of the study coincided with curriculum decisions being made in South Australia in R - 7 science. However whilst lists of preferred topics and methodologies have been collected it is evident that much of the data, particularly that from the science topics inventory, is of limited assistance to curriculum planners and teachers.

Naively perhaps it was anticipated that, though there would be individual differences, the interests of year 7 students would show some pattern. Inspection of the first list in Table 1 reveals that this is not the case, and the reason is clear - the large differences between the interests of boys and girls. It is only when the boy's and girl's top 20s are separately considered (Table 1) that patterns are observed and for the teacher of a mixed class, that is all teachers in South Australian state primary schools, there is little which can shed light on practice.

If catering for students interests in specific topics is seen to be of importance two classroom practices which take account of these data might be considered. Either individual students might be allowed to construct their own programmes by selecting from a wide variety of topics or, if whole class teaching is to be preferred, the teacher might select topics which are representative of the full breadth of science so that all students' interest can be met at least part of the time.

In the case of preferred teaching methodologies the picture is somewhat brighter as, for the most part, boys' and girls' interests coincide (Table 3). While there were statistically significant differences in the mean score on some of the methodologies the message of most consequence was the very similar rank order of preference. Both sexes prefer those methods involving some degree of practical activity and independence, together with audiovisual methods, nevertheless there is not total agreement on what methodologies satisfy the former requirements. These results are in accord with those of Keightley (1980) who showed similar methodological preferences for the sexes in her study of year 11 biology students.

This brings us to a further point. Clearly a most important result of this study is the vast difference in interest towards particular areas of science shown by boys and girls. This result is not totally unexpected. Meyer (1963) in a study in Sydney schools showed similar differences, but attributed these to the historical fact of different science curricula in boys' and girls' schools. However Foster (1967) in Victoria, and Sumner and Wilson (1972) in South Australia had similar findings despite the science curriculum for boys and girls being identical.

In this present study, as in Meyer's (1963), the overall difference in science interest was minimal and because of sex bias on virtually every item it would be difficult to develop a scale to measure overall interest validity. Only an approach similar to that adopted in IQ tests, where sex bias is deliberately eliminated, would be appropriate. Yet boy-girl differences, similar to those observed previously in Australia, and elsewhere, exist and, as the science content of the curriculum for boys and girls is identical, Meyer's comment that a common curriculum for the two sexes would significantly reduce or remove these differences may appear to have little foundation.

Nevertheless, content is only one area where curriculum might exert bias and one primary science adviser recounts anecdotes of both male and female teachers with male students crouching around physical science apparatus whilst, with little expectation of their interest, the girls were allowed to wander away. Whether such differences in treatment are common would appear to be an important area for research.

An obvious question here is, do these differences in interest matter? Without going into detailed argument we think they do. Thus a further area for research is whether they can be reduced, the major concern here being that of the physical sciences. While there are significant differences in the other

areas also, both sexes do show a positive interest in the general and human biology areas, and in earth science girls are no worse than neutral toward the area. But in the physical sciences the difference is very large and 30% of the variance can be accounted for by the sex-group membership. Girls are definitely negative towards physical sciences, and if interests affect choices (Meyer, 1963) then the established pattern of girls selecting biological science not necessarily because they particularly like it (Keys and Ormerod, 1976), is perpetuated. Does this matter? Without going into detailed argument we believe it does. As a result of a difference in interest, which is almost certainly mainly socially determined, the eventual career choices open to many girls are being restricted. In addition an adequate knowledge of the physical world is necessary for all students to assist in the complex decisions necessitated by our technological society, and by opting out of the physical sciences girls are less likely to develop such knowledge.

To what extent the year 7 teacher or the teacher at any other level can affect students' interests in different areas of science is not known and it is intended that further research will be directed to that question.

If it is planned to intervene, two aspects need to be considered - first, possible strategies for intervention and secondly the means of monitoring such intervention. As one possible strategy we have already indicated the potential use of preferred methodologies, together with some choice of methodology.

For a teacher to monitor the success of an intervention a more manageable instrument than that used in this study is required. For this purpose a 20 item instrument consisting of 4 sub-scales with 5 items in each of the areas, physical sciences, human biology, general biology and earth science/astronomy is being developed.

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UNIVERSITY STUDENTS' EXPECTATIONS OF GEOGRAPHY, CHEMISTRY AND BIOLOGY
COURSES WITH SPECIAL REFERENCE TO STUDENTS' PERCEPTION OF GEOGRAPHY

Paddy Lynch and Andrew Davey

INTRODUCTION

Most modern science curricula are constructed according to a fairly well-defined set of aims, and much debate has centred on the problem of relating these aims closely to assessment. Geography is no exception; since the early 1960's geographers have tended to adopt similar lines in curriculum development to those followed by science educators. Geography has consequently developed into an applied science with all its characteristics: measurement, observation, hypothesis testing, data interpretation, practical or field studies etc. Or has it? An understanding of students' perception of their courses would seem to be a useful guide in regard to this question. To what extent students' perceptions of geography compare with their perceptions of say chemistry and biology has not been reported. In fact very little has been written about students' perceptions of their subject, instead the tendency has been to focus on teachers and their aims.

This paper examines the perceptions of first year university students of geography, chemistry and biology and their expectations of the university courses in question. These expectations are based on pre-university experience; student perceptions at this transitional period are important in that they have implications for the socialisation process that goes on in the first year of university studies and for end of year performance.

Description of the Variables Termed Expectations

The variables termed 'expectations' consist of 32 items (see Table 1) which were derived from a carefully refined list of stated 'aims' of science curricula. The derivation required minor but important syntactical changes. 'Expectation' was understood by students to mean 'what I hoped for' in accord with research intentions. This was established by interview. At the same time it was established that student perceptions of university work were based mainly on their experience of secondary work and were affected by the views of teachers and the media.

The list of expectations was then arranged into four groups concerned with the acquisition of (a) knowledge; (b) cognitive skills; (c) laboratory and/or field work; and (d) long term goals and attitudes.

PROCEDURE

Construction and Administration of the Questionnaires

The Questionnaire list of 32 expectations was developed from previous work (Frazer, Palmer and Sleet, 1976; Lynch, Waters and Gerrans, 1980).

The original list was obtained after a literature search and appropriate group validation in respect to expectations of first year Chemistry courses. It was clear that the items applied equally well to physics and biology and with relatively minor modification would apply to geography. Each expectation was

TABLE 1 - The list of expectations on the student questionnaire

EXPECTATIONS: GROUP A

1. To improve my knowledge and understanding of the historical development of geography
2. To improve my understanding of the basic principles of geography
3. To make me aware of the economic implications of geography
4. To show me how geography is related to other science subjects
5. To improve my understanding of the application of geography to industry and commerce
6. To increase my factual knowledge of geography
7. To make me aware of the moral and social implications of geography
8. To improve my understanding of the application of geography to environmental problems
9. To improve my knowledge of the organisation and functions of science based industries
10. To improve my understanding of how theories can explain experimental or field observations

EXPECTATIONS: GROUP B

11. To improve my ability to think in abstract terms (ie. to think about things that cannot be seen or handled)
12. To improve my ability to think logically
13. To improve my ability to learn independently
14. To teach me how to develop approaches or ideas, new to me, when called upon to solve a problem
15. To improve my skill in oral communication
16. To improve my ability to solve new problems in geography by using basic principles and concepts

EXPECTATIONS: GROUP B (CONTINUED)

17. To improve my skill in written communication
18. To develop, in me, an ability to design experiments or investigations
19. To teach me how to obtain relevant information from the literature and other sources

EXPECTATIONS: GROUP C

20. To improve my ability to work safely in a laboratory or in the field
21. To improve my manipulative skills in the laboratory or in the field
22. To improve my ability to make careful observations
23. To improve my ability to conduct experiments or field research in an organised way
24. To improve my ability to interpret observations in a logical way
25. To make me aware of the importance of accuracy in experimental or field research calculations
26. To make me aware of the importance of writing an accurate experimental or field report

EXPECTATIONS: GROUP D

27. To develop my ability to undertake employment in many fields of geography (or related to geography)
28. To develop, in me, an ability to do research or original work
29. To develop, in me, an ability to work with a team or in a group
30. To increase my interest in the theoretical and conceptual structure
31. To make me more open minded about careers outside geography
32. To increase my interest in experimental or field research work

thus written so that its stem applied to geography, chemistry and biology. Thus, expectation 6 becomes 'To increase my factual knowledge of "x" ' where "x" is geography, chemistry or biology.

Three questionnaires were produced, one for each subject area. In the geography questionnaire, all 32 expectations refer specifically to geography, and similarly in the chemistry questionnaire and the biology questionnaire. See Table 1 for the example for geography.

The order of the items contained in the four relatively distinct groups of expectations (knowledge, cognitive skills, laboratory work, and attitudes and long-term goals) was randomised. Students were required to indicate the four most important expectations in the first two groups (of 10 and 9 items, respectively) and the three most important expectations in the other two groups (7 and 6 items). For each group there was the opportunity to indicate the category 'no particular preference' amongst the expectations. Less than 10% of students used this category. The purpose of the questionnaire, given in its introduction, was read to the students during a short preamble aimed at winning their cooperation. Students were asked to select the most important influences from any particular group according to the instructions. They were taken through the questionnaire section by section and asked to read carefully each set of items several times before making any selection. The questionnaire was administered during a normal lecture period in the second week of the students' first term at university. The time for completion excluding the preamble was approximately 20 minutes.

In order to establish the relative importance of expectations within each group we decided to use a forced choice technique for scoring items. It will be appreciated that if the relative difference between say 'expectations associated with knowledge' is small then one would expect average responses for all items to be of the order of 0.4 (40%). Field test findings showed average responses approaching 1.0 and 0.0 which indicate that items are not perceived by students to be of comparable importance.

At the end of the questionnaire students were required to choose the four most important expectations from the fourteen that they had chosen from the separate categories. It will be appreciated that there are no category boundaries for this final test and the results, therefore, represent the relative importance of all 32 expectations.

Subjects

The most appropriate time at which to administer the expectations questionnaire was during the first week or so of university study. In this survey, responses were obtained from newly enrolled students at the University of Tasmania in geography (59), chemistry (130), and biology (80); and Monash University in geography (89), chemistry (188), and biology (114) in 1979. In subject areas where large course numbers required several parallel lecture groups, a single group was used.

ANALYSIS AND INTERPRETATION

If, on a single questionnaire, an expectation is chosen it scores 1, if not chosen it scores 0. Thus it is possible to calculate the index n/N , the number of respondents choosing the item (n) divided by the total number of respondents (N). This allows estimation of the relative importance of each expectation. These indices were calculated as percentages for the responses of geography, chemistry and biology students and the cross-subject comparisons are made for each category of expectation. See Table 2.

TABLE 2 - The percentage responses of first year University students
in Biology, Chemistry and Geography to the list of
32 expectations of first year courses

Item No.	Content	Biology Students ^a	Chemistry Students ^b	Geography Students ^c	Sig ^d
<u>Knowledge</u>					
8.	Environmental Applications	70	49	78	*
2.	Basic Principles	79	79	75	
6.	Factual Knowledge	79	68	62	*
4.	Relation to Other Science Subjects	42	64	33	*
10.	Theoretical Explanation of Observations	42	47	32	*
7.	Moral and Social Implications	25	14	29	*
3.	Economic Implications	5	6	23	*
5.	Application to Industry	14	25	13	*
1.	Historical Development	10	4	9	
9.	Organisation and Functions in Industry	11	15	8	
<u>Cognitive Skills</u>					
12.	Logical Thought	61	69	57	
14.	New Approaches to Problem Solving	68	68	54	*
16.	Using Basic Principles to Solve Problems	61	64	48	*
13.	Independent Learning	45	43	43	
19.	Literature Searches	33	25	40	*
17.	Written Communication	14	8	32	*
11.	Abstract Thought	30	35	26	
18.	Experimental Design	47	47	25	*
15.	Oral Communication	9	7	12	
<u>Lab & Field</u>					
24.	Interpret Observations Logically	71	68	66	
22.	Careful Observation	71	57	59	*
23.	Lab/Field Organisation	54	49	40	*
21.	Lab/Field Manipulative Skills	38	51	25	*
26.	Lab/Field Report Writing	24	19	22	
25.	Observation Accuracy	19	24	19	
20.	Lab/Field Safety	4	12	2	*
<u>Long Term Goals & Attitudes</u>					
28.	Research	65	63	51	*
32.	Experimental/Research Interest	52	43	46	
30.	Theoretical Interest	43	43	42	
27.	Employment	63	48	33	*
29.	Teamwork	31	39	31	
31.	Outside Career Openmindedness	21	23	25	

N=194^aN=318^bN=346^cd Significant if $p \leq .01$.

Expectations Associated with Knowledge

The three main choices of expectations, 'environmental applications', 'basic principles', 'factual knowledge' are not only dominant for the knowledge category but for all items on the geography questionnaire.

There are seven expectations which are significantly different when subject area is considered. Considerable differences are observed between responses for 'environmental applications' (29%) and relation to other science subjects (31%). However, the rank order of expectations is not too dissimilar for all these subject areas.

Expectations Associated with Cognitive Skills

There are differences in expectations among subject areas for items 14, 16, 17, 18 and 19. Geography students have low expectations for aspects of 'problem solving' and 'experimental design' and higher expectations for 'written communication' and 'literature searches'. However, the rank order of items in this category is once again similar for all three subject areas.

Expectations Associated with Laboratory and/or Field Work

There are differences among the subject areas: geography students have lower expectations for 'careful observation' (than biology but not chemistry), and understandably, lower expectations of 'lab/field organisation' and 'manipulative skills'. The rank ordering of items for subject area is virtually identical in all three cases.

Expectations of Long Term Goals and Attitudes

There are some substantial differences between subject areas in long term goals associated with 'research' and 'employment in that subject area'. Surprisingly, biology students are more vocational in this respect than chemistry students.

Final Four Expectations

The students had the opportunity to select the four most important expectations from their previously chosen fourteen. This was to enable us to examine the emphasis for the four different categories of expectations when category boundaries are removed as well as to detect the dominance of any particular expectation. See Table 3 for a record of the choices made.

These observations seem well worth commenting upon.

- (1) Students in all three subject areas chose substantially from all four categories: knowledge, cognitive skills, lab/field skills, and long term goals and attitudes. The recorded 'total responses for category' indicate that the expectations of geography students are more dominated by the 'knowledge' category than for chemistry and biology but the total responses for 'lab/field skills' are virtually identical.

TABLE 3 - Student Expectations (% responses) :
Final four expectations test

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STUDENT EXPECTATIONS ASSOCIATED WITH KNOWLEDGE

Item No.	Biology Students ^a	Chemistry Students ^b	Geography Students ^c
8. Environmental Applications	30	19	50
6. Factual Knowledge	37	25	34
2. Basic Principles	31	32	31
4. Relation to Other Sciences	7	17	9
10. Theoretical Explanation of Observations	7	9	8
7. Moral and Social Implications	7	4	14
3. Economic Implications	0	1	8
5. Application to Industry	4	6	4
1. Historical Development	1	1	3
9. Organization and Functions in Industry	1	2	3
Total responses per category	125	106	164

STUDENT EXPECTATIONS ASSOCIATED WITH COGNITIVE SKILLS

12. Logical Thought	19	29	27
14. New Approaches to Problem Solving	20	23	22
16. Using Basic Principles to Solve Problems	16	20	15
13. Independent Learning	14	13	14
19. Literature Searches	6	6	10
17. Written Communication	3	0	9
11. Abstract Thought	6	8	8
18. Experimental Design	12	12	5
15. Oral Communication	2	2	5
Total responses per category	98	113	115

STUDENT EXPECTATIONS OF LABORATORY AND/OR FIELDWORK

24. Interpret Observations Logically	31	27	27
22. Careful Observation	21	16	18
23. Lab./Field Organisation	8	12	13
21. Lab./Field Manipulative Skills	6	13	7
25. Observation Accuracy	3	5	2
26. Lab./Field Report Writing	4	5	2
20. Lab./Field Safety	0	2	0
Total responses per category	73	70	69

EXPECTATIONS ASSOCIATED WITH LONG TERM GOALS AND ATTITUDES

28. Research	28	28	14
27. Employment	37	27	16
32. Experimental/Research Interest	10	12	11
30. Theoretical Interest	4	6	11
29. Teamwork	7	10	8
31. Outside Career Openmindedness	5	7	7
Total responses per category	91	90	67
N =	194 ^a	318 ^b	146 ^c

- (2) Within the four areas there are individual expectations which are major. For geography students, 'environmental applications' is seen to be a major focus, and responses for this item are significantly more than any item on the test for any sub-group. Geography students do have definite expectations of long term goals and attitudes but these are less dominant than are observed for chemistry and biology students. In the latter groups, 'research' and 'employment in that subject area' are major expectations of new students indicating a clear employment orientation.

CONCLUSION

First year students in geography, biology and chemistry indicate many similarities in their expectation of university courses. There are some interesting differences when categories of expectations are considered in isolation and when students are allowed to choose in the 'final four' expectations test. Expectations of geography are quite definitely science oriented if one assumes that a 'practical', 'problem solving' approach is inherently scientific. If these orientations are a consequence mainly of experience, and this would seem to be very likely, then one needs to consider carefully the appropriateness of these orientations. There are aspects of these results which should be of interest to curriculum developers and educators interested in a broad evaluation of student goals.

Students' expectations emphasize knowledge, thinking skills, experimental work and related skills, as well as long term goals and attitudes. There is certainly an element of general balance which must be heartening to those who might have had doubts about the motivation of new university students. Students have expectations which indicate that they are aware of and presumably value all four categories of goals.

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